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THE AMERICAN

METEOROLOGICAL JOURNAL.

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METEOROLOGY AS THE PHYSICS OF THE ATMOSPHERE.

PROF. WILHELM VON BEZOLD.

[*Translated by* PROF. CLEVELAND ABBE *from* HIMMEL U. ERDE, *Oct., 1892, Vol. V., pp. 1–19, and published by permission of the Author.*]

FROM the earliest times up to the middle of the present century, meteorology rested substantially upon a statistical-geographic basis, and the works of an Alexander v. Humboldt, a Dove, and others relate far more to the study of climate than to meteorology proper.

When in the middle of this century we began to free ourselves from the consideration of average values which until then had been almost the exclusive practice, and began to study the condition of the atmosphere at consecutive, equidistant moments of time, and to depict this condition on the so-called weather charts, we were then for the first time able to make the weather, in the strictest sense of the word, the subject of study; and from this time forward meteorology, which before was nothing more than climatology, had a perfect right to its name.

This new apprehension of the subject showed the need of a more profound and rapid investigation of atmospheric processes than had been hitherto possible; it demanded the application to meteorological problems of the principles of general mechanics as well as of thermo-dynamics or the mechanical theory of heat.

Thus a new field of investigation was opened up which in America, where this new study had its birthplace, thanks to the highly meritorious pioneering works of the late Prof. William Ferrel, was called "Dynamic Meteorology," but which, however, may be better and briefly designated as "Theoretical Meteorology."

These researches have, year by year, taken up more space in current scientific literature since such European investigators as Reye, Hann, Guldberg, Mohn, etc., have successively entered the field of contest.

This may in part be attributed to the fact that Sprung's "Lehrbuch der Meteorologie," which appeared in 1885, first placed within the reach of wider circles the works of the above mentioned scientists, which until then had been scattered and difficult of access; but, above all, it may be ascribed to the tendency of our day, which is to constantly extend the application of strict mathematical-physical methods.

But in consequence of the more intense development of this method of studying the subject there has, already, in the course of even a few years, taken place a perceptible change and clarification of our views in meteorology, while, on the other hand, it has brought us to new problems, the happy solution of which is to be expected only from the co-working of theory and observation.

It may, therefore, be permitted here briefly to describe the problems which at present are the subject of theoretical investigation, and at the same time to point out what new problems have grown out of the new position of the questions of observational meteorology as thus materially changed by looking at them from a theoretical point of view.

The theory of the general circulation of the atmosphere is that which at present especially claims our attention. It is well known that in former years we had only the simplest idea of this general circulation. It was thought possible to attribute to the whole atmosphere the conception of a lower stream flowing to the equator and an upper stream flowing to the poles, such as we had recognized in the region of the tropical seas within the trade-wind region, and the key to the solution of all weather phenomena was found in the theory of an equatorial and a polar stream.

When, however, we began to make weather maps, and perceived from them that the so-called trade-wind theory was not sufficient, at least for the middle and higher latitudes, but that, on the contrary, the formation and movement of regions of lower and higher atmospheric pressure (the so-called barometric maxima and minima) is that which decides the character of the

weather, then the old theory was thrown aside, and all our strength was given to the investigation of the processes within these areas.

It was recognized that the barometric minima or depressions (which are called cyclones on account of the manner in which the wind circles around them, and which, in general, agrees with that in the whirlwind storms) are regions of rising air-currents; whereas, on the contrary, we have to do with descending currents in the regions of high atmospheric pressure, or the so-called barometric maxima or anticyclones.

At the same time, the fact that the depressions bring dull, rainy weather, whereas in anti-cyclones the sky is clear and the air is dry (except for the fog that occurs in the lowest strata at the colder hours of the day and seasons of the year), found its simple and natural explanation in the ascending or descending currents, as they had learned to understand them by the application of the mechanical theory of heat to the phenomena of the "Foehn."

Since it also appeared that cyclones occur preferably over warm regions, whereas the barometric maxima develop especially over relatively cooler regions of the earth (in summer over seas and in winter over continents, particularly over the great north-Asiatic continent), so nothing was more natural than to seek the reason for these phenomena solely in local warmings and coolings [of the lower strata of air].

In fact, until very recently, it did appear as if such local warmings over special portions of the earth's surface, together with abundant moisture, and as if cooling in other places, both in combination with the deflecting power of the rotation of the earth, were quite sufficient to explain the origin of cyclones and anticyclones, while the reason for the peculiar propagation of the whole system of winds and pressures was found in the inflow of warmer air on one side of the cyclone.

During the last decade meteorological research has been particularly devoted to the development of this theory, the so-called convection theory; and especially were cyclones regarded as the dominating element (even now in every weather report, the position and progress of the depressions are first mentioned), and to the study of these Ferrel first invoked the aid of mathematical analysis.

In fact we have here to do with particularly difficult and com-

plex problems, whose solution can only be attempted by simplifying hypotheses. But we have succeeded in establishing a series of important propositions, in that we have considered a cyclone as a definite system, and have confined ourselves to investigating the conditions that must be fulfilled in order to bring about their long continuance, or their continued renewal, as well as their uniform progressive motion, and further in that we have treated the processes of motions, as also the thermal processes, each by itself alone.

A few years ago the opinion was entertained that an ultimate stage had been reached in this branch of science, if not as to the details, at least as to the essentials, and that it only remained to still further develop and enlarge the fundamental ideas It was, however, recognized that there remained still one important question which the convection theory was powerless to answer. Even although the fact that barometric depressions in general follow certain definite courses could be naturally combined with the new views, still the continued generation of new cyclones at nearly equal intervals of time remained unexplained.

Even if this were a defect, it could not be regarded as a reproach against the correctness of the whole theory since it did not exclude the possibility that some new observation, or a lucky idea, might lead to the solution of the riddle.

On the one hand, the results attained during some years past, and above all the observations made on the "Sonnblick," in the upper Tauern (at an altitude of 3,100 meters), as discussed in a masterly way by Hann, at Vienna, have, in fact, brought to light, important objections as to the applicability of the hitherto accepted theory.

If, namely, the rarefaction of the air as it manifests itself by the low state of the barometer within the cyclone, or if the condensation of the air within the anticyclone were really the first cause of the phenomena, then either would bring about, first the ascent or descent of the air in the respective regions whence would follow the totality of the processes observed within these cyclonic and anticyclonic systems ; hence it follows that the columns of air must unquestionably have a higher temperature in the cyclone than in the anticyclone.

If, however, this is not the case, then the rarefaction of the

air within a region of depression must be a consequence of the whirl, and not the whirl a consequence of the rarefaction, and the whirl must act still more like a centrifugal ventilator, in which the air is thrown out by the rotation and a rarefaction is produced within, with its consequent indraught.

As long as observations from the deeper lying strata, that is the observations from the ordinary meteorological stations, were the only ones consulted, it seemed as if the first-mentioned conditions were fulfilled, for, as already remarked, in general, cyclones are associated with relatively warm, and anticyclones with cold places on the surface of the earth.

On the other hand the observations at high stations, particularly those made on the "Sonnblick," teach that when we consider the upper strata the conditions are frequently reversed, and often the entire column of air within an anticyclone, as far up as it is accessible to our observation, is much warmer than the corresponding column within the neighboring depressions.

These facts, which are in fullest accord with the principles of the mechanical theory of heat, imperatively demand that the whole theory of the origin of cyclones and anticyclones, as hitherto taught, be subjected to a thorough revision.

This necessitates restoring to critical study that general circulation of the atmosphere, which, under the old trade-wind theory, was considered as the only controlling power, but which for several decades has been entirely set aside, and necessitates inquiring by what system it is possible to establish a connection between the trade-wind theory and the convection theory, which latter had certainly given us correct views on many points. This inquiry is as much a work of correcting, completing, and broadening our theories as it is of obtaining new materials from observation.

It is scarcely possible to give outsiders an idea of the way in which one goes to work in such theoretical investigations, and therefore I need only observe that, at first, one makes the simplest possible assumptions and then gradually other collateral circumstances, one after the other, are taken into consideration in order step by step to arrive at the truth.

For example, as already remarked, cyclones and anticyclones have hitherto been looked upon as independent formations without taking into account forces (except the friction at the surface

of the earth) which act upon them from without; whereas we must consider these outside influences if we would take into account the influence of the general circulation.

Similarly in those researches no account was taken of the fact that one part of the cyclone appertains to the lower, dry air, the other part to the cloud region, and that, on entering into the latter, entirely different conditions suddenly come into play that must exert an influence upon the atmospheric movements. Again, the gain or loss of heat at the upper boundary of the clouds has been, until now, entirely neglected in theoretical researches, although precisely here it is that we have to do with processes of fundamental importance.

It may indeed appear hopeless, even to attempt to free oneself from the conditions hitherto imposed and to consider all the aforesaid circumstances, since the problems, when considered in such generality, are more difficult and complex than any problem in theoretical astronomy or mathematical physics that the human intellect has as yet succeeded in solving.

Notwithstanding all this we must not despair of being able to advance, even in this subject, at least so far as may be necessary, in order to understand the most important points, and indeed, simple considerations from very general points of view promise better results than those detailed studies by which we have been led into error on account of the abundance of the minutiae.

For example, although the principle of the conservation of energy frequently enables us to solve questions of great generality and to give correct answers as to the final results, still we are far from being in a position to unravel the tangle of threads which bind the individual phenomena together.

And the same may be said of other propositions in general mechanics or thermo-dynamics.

For instance, the very simplest considerations suffice to show that the great circulation or (if we use the ordinary language of the mechanical theory of heat) the great circular process as we find it in the general circulation of the atmosphere and as it is essentially completed within the tropical and sub-tropical zone, is of an essentially different nature from the smaller circular processes as they go on in higher latitudes in the interchange of air between cyclone and anticyclone. In the former, heat is exchanged for work; in the latter, work is converted into heat,

and it is the movements produced by the general circulation that, at least in part, sustain the smaller circulatory processes.

In the same way conclusions of the highest importance may be drawn from the simple consideration that in atmospheric processes, and, in so far as we consider only their average values, we have, in general, to deal with so-called steady, or, more strictly speaking, with periodically steady conditions.

A state of motion is called steady motion when, in any given system of points, the movements succeed each other in a series such that in the place of the elementary particles as they respectively move further along, new ones constantly arrive, which move in precisely the same manner, so that the system as a whole, always remains in the same given condition, although its individual particles are in motion.

For example, when a fly wheel revolves on its axis with uniform velocity this is a steady process; when the stage of water in a river remains constant, so that as much water always flows into it as flows out, we have to deal with a steady condition and indeed with a steady flow. The same is true of the motion of water or of gas in pipes, as long as the water supply and gas production and the consumption remain constant.

In all such cases we have to do with a certain condition of equilibrium, although no equilibrium is present in the narrower meaning of the word since movements are going on, and the individual particles are not at rest.

The fly wheel, which in order to make the illustration entirely applicable we must think of as a complete circle, gives the spectator, so long as he does not come too near, the impression of complete rest; the river as a whole remains in its place, notwithstanding that the particles of water which compose it move and are constantly renewed.

If the conditions here described are not precisely fulfilled; if the system, as such, does not remain unchanged, but if after definite equal periods of time it always returns, and always in the same manner, to the same condition, then we may describe the process as periodically steady or as a steady period.

A steam engine, and by preference a fixed one, in which at every stroke of the piston the same performance is repeated, and which, at equal intervals of time and with equal consumptions of fuel, always does the same amount of work, offers an excellent

example of such a periodic steady condition. It is the same with the processes within a gas pipe, through which during the daytime only a feeble current flows, which every evening must increase in strength with the increasing consumption, but in the morning hours must again become weaker and weaker.

In meteorology, and in so far as we consider only the general averages, we have now almost always to do with similar steady periodic processes.

Thus, for instance, on an average, the earth receives during a year as much warmth from the sun as it loses by radiation into space; were this not the case it would become steadily colder or warmer, which, however, is demonstrably not the case, so long as the investigation is limited to the historical period and is not carried on by hundreds of thousands of years as is done by the geologists. Moreover, in some places and at fixed annual and diurnal periods, the insolation is in excess; in other places and at other times the radiation outwards is greater, and in this way the earth's store of heat presents to us the realization of a steady periodic movement of heat which is subject to regularly recurring variations, but shows in general a certain degree of permanence.

Analogous phenomena occur in the currents of the atmosphere which, after smoothing away the local or accidental details, may also be regarded as periodically steady processes.

Now, it is possible to establish certain general propositions as to steady movements and currents which may be proven to be particularly useful in meteorology.

Although we might well become bewildered at the thought of the complicated paths that a particle of air has to traverse when ascending at the equator, after crossing the tropics, it again descends only to be drawn into one of the great whirls revolving about the polar regions from west to east, and finally, after numerous ascents and descents in cyclones and anticyclones, after frequently repeated absorptions and radiations of heat, returns again to the point of departure; yet we should not lose courage, but at least endeavor, sustained by the principles of physics, to follow our particle in its course by employing strictly mathematical modes of thought.

Of course it is necessary in such work to proceed cautiously, every conclusion should be carefully weighed, and with pitiless criticism tested by comparison with the facts of nature.

Although we are in meteorology not in the same position as the members of "Accademia del Cimento," to whom we are indebted for the first meteorological instruments, and who, in the spirit of their teacher and predecessor Galileo Galilei, had inscribed upon their banner the experimental testing of every conclusion, still their motto, *provando e riprovando*, that is, "by trial and repeated trial," may also, in a certain sense, be appropriate for us.

It is, indeed, denied to the meteorologist to carry on experiments, but he can, at least, prove the correctness of his conclusions by comparison with the phenomena actually observed; and if only we do this thoughtfully and fairly then may we hope at some time, if only in the distant future, still eventually, to reach our goal, or at least, to smooth the way which will finally lead to it.

In order to attain this end, it will indeed be necessary to extend in many directions the programmes of observations as has already, here and there to a modest extent, been done, but which must be still more energetically prosecuted, if we wish to faithfully perform our duty towards the problems that the progress of science at present sets before us. It is easy to see what direction this extension must first take. The convection theory, which we have just seen needs a revision, was developed principally upon the basis of observations made at the earth's surface.

As soon as we began to place observing stations at higher and higher elevations, defects in this theory became evident, which we have not as yet succeeded in completely removing. Thus we are naturally led to give more and more attention to observations made in the higher regions of the atmosphere.

It does not, however, suffice to merely increase the number of mountain observations, desirable as this is in itself, but it is, above all, necessary to penetrate, with all the means at our disposal, into the real field of our investigations, *i. e.*, into the free atmosphere.

In fact, the meteorological conditions at the stations on the mountain tops are merely a transition stage between those of the lowland stations and those prevailing in the upper regions, since all the observations obtained there are still, to a high degree, dependent upon the influence of the earth's surface which latter, even on the steepest mountains, only rises gradually to the sum-

mit, as is shown by every good relief map. It is only when we have accurate knowledge of the direction and extent of the differences which exist between observations made in the free atmosphere and those made at the mountain-top stations, that these latter are estimated at their true value.

The determination of these differences and the investigation of the condition of the free atmosphere can only be done by means of the balloon; in comparison with which mountain-top stations, as well as cloud observations, must be considered as being merely supplementary.

The balloon has, moreover, attained its real importance only in the most recent times, since the ingenuity of Assmann has enabled him to overcome the great difficulties experienced until now in ascertaining exactly the temperature and moisture during balloon voyages.

It is, perhaps, not generally known that an irreproachable determination of the temperature of the air under the ordinary conditions was still an unsolved problem until within a few years, although the observation of temperature has always been looked upon as one of the most important problems of the meteorological stations.

(*To be continued.*)

CHARTS OF STORM FREQUENCY.

PROF. CLEVELAND ABBE.

IN August, 1891, in conversation with Dr. Koeppen I learned that the work published under the title, "Statistical Atlas of the United States," in 1874, by Gen. Walker, who was at that time Superintendent of the Ninth Census, was but very little known among the meteorologists of Europe, and that consequently the maps compiled by me for the Signal Office as its contribution to the physical charts of that atlas were quite unknown. Among these, Chart VI., showing the frequency of storm centres was, as I supposed, at that time not only original but novel. The subsequent publication by Dr. Koeppen of a storm frequency chart for Europe was really based upon a different method, and therefore does not quite represent the same idea. The charts compiled by Lieut. John P. Finley and published in his "Charts

THE NUMBER OF STORM-CENTRES THAT PASS OVER EACH QUADRANGULAR DEGREE IN ONE YEAR, DEDUCED FROM THE AVERAGE OF THE TWO YEARS, MARCH, 1871, TO FEBRUARY, 1873, INCLUSIVE.

LONGITUDE WEST FROM GREENWICH.

Lat. 50°	Sec. Lat.	100°	99°	98°	97°	96°	95°	94°	93°	92°	91°	90°	89°	88°	87°	86°	85°	84°	83°	82°
49°	1.54	–	5.5	6.5	6	4	3	3	6.5	7.5	8.5	6.5	7	6.5	7.5	6	5	6	4 5	4.5
48°	1.51	–	6.5	7.0	8	7	8	10.5	11	12	16	15.5	16	16.5	17	15.5	15	11.5	10	10.5
47°	1.48	–	8.5	6.5	7	8	9.5	10	14	13 5	12.5	16	19	21	19.5	18.5	18	16.5	16.5	18
46°	1.45	–	9.5	10.0	10	10	10	11.5	11.5	13.5	12	14	13.5	16	14.5	18	17.5	17 5	20	21.5
45°	1.43	–	9.5	9.0	9.5	9	11.5	10	9	16	16.5	14.5	11.5	13.5	14.5	15	21	23.5	21	21.5
44°	1.40	–	14	11	12	12	9.5	10	8.5	12	8.5	10.5	12.5	17	14.5	14.5	15.5	19	18.5	18
43°	1.38	–	22.5	18	15.5	10	10.5	12	10	10.5	14	14 5	13.5	11	7	8.5	11	11	14	13
42°	1.36	–	19.5	20	18	16.5	15	14	12 5	11	12	11	7.5	9	6.5	7.5	9	9	8.5	10
41°	1.34	–	10.5	15	16.5	14	12	14	13	13.5	12	11.5	8 5	7.5	8	10.5	10	10.5	10	9
40°	1.32	–	8.0	9	13	11.5	12	14.5	12	14.5	12.5	11	11	11	11.5	9.5	6.5	5.5	5.5	5
39°	1.30	–	7.5	9	10 5	7.5	11	11	9	11	10.5	9	10.5	11	7	9	6	7	5	6.5
38°	1.28	–	5 5	8	9.5	10	10	8	9	8.5	8	8	3.5	6	6.5	6	8	6	5.5	7.5
37°	1.26	–	2.5	3.5	8	6	4.5	4	5	6.5	6	6 5	6 5	5	6.5	5	5.5	5	3	3.5
36°	1.24	–	1.5	4	5.5	5.5	5.5	5.5	4.5	4.5	5	4.5	6.5	4.5	3	3.5	3	3.5	4 5	4.5
35°	1.23	–	1.5	2	3.5	2.5	3.5	5	6	4.5	3	3 5	2.5	2	1	1	1.5	2	3.5	3.5
34°	1.21	–	1.5	3	3	2.5	2.5	3	4.5	3	2	2	2	1	1	2	2	1.5	1.5	4
33°	1.20	–	2.0	2	5	6	4	5	4.5	2.5	3	2.5	1.5	0.5	1	2	2.5	2	2.5	5
32°	1.19	–	1.5	2.5	6	6.5	6	4	4	2.5	2.5	2	2	2.5	3	4	4	3	4	7.5
31°	1.17	–	1.5	3	6	5	4.5	4	3.5	3	2	3	2.5	3.5	5.5	4	5	3.5	4 5	7
30°	1.16	–	1.5	3	5	3	4.5	3	3.5	4.5	4.5	4	6	5.5	4	2	3	4	6	6
29°	1.15	–	1.5	2	3	3.5	3	3.5	2	2.5	3	4.5	5	4 5	4	3.5	5	5.5	6	4.5
28°	1.14	–	1.5	2.5	2.5	2.5	3	2 5	2.5	3	3	3 5	3.5	4.5	5.5	6	8	6.5	5.5	4.5
27°	1.13	–	1.5	1.5	1	2.5	3	4	3.5	3	4	3	6	4	5	5.5	6	2	1.5	1
26°	1.12	–	1.5	2	1.5	3	3	1.5	3	2	2 5	3	4	3.5	3.5	2.5	2	0.5	0	1
25°	1.11	–	1.5	2	2	2	2	1.5	2	2	1	0	1	2	1 5	2	2	0 5	0	0
24°	1.10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23°	1.09	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22°	1.08	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
21°	1.07	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20°	1.07	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Lat. 50°	81°	80°	79°	78°	77°	76°	75°	74°	73°	72°	71°	70°	69°	68°	67°	66°	65°	64°	63°
49°	3.5	5	5	5	5	3.5	2	2	2	2.5	1	1.5	2.5	1.5	3.5	4	1	1	–
48°	8 5	7.5	7	6.5	7	6	4.5	4.5	4	5.5	5	5.5	7.5	9.5	14	10	6.5	4	–
47°	18	14.5	14	15	15.5	17.5	17.5	14	12.5	15	16	11.5	17	18	16	11	9.5	7.5	–
46°	18.5	20	21	22	21	20 5	20.5	24	22	24	26	24	22	16 5	12.5	9.5	6.5	4.5	–
45°	21.5	24	21	20.5	23.5	24	21.5	21.5	22.5	23.5	24	19	18	19 5	15.5	12	9.5	5 5	–
44°	20.5	22	21	20.5	23	21.5	22	21	22	15.5	15.5	16.5	16.5	14.5	17.5	19	12	6.5	4
43°	13	16	19	20.5	18.5	18	16	16.5	14	15	14	14	17	18.5	20.5	18.5	14.5	6.5	3
42°	12.5	12.5	11	12	12 5	13.5	12.5	10.5	12	13.5	12.5	13	18.5	20.5	16.5	14	9.5	3.5	1
41°	8	7.5	8.5	9.5	9.5	9.5	7	6 5	8.5	10	12	12	12	14	12	8	4.5	2.5	–
40°	5.5	5.5	6.5	4.5	4	3.5	4	4	8	10.5	12.5	13	10.5	11.5	6 5	2.5	2.5	1	–
39°	7.5	6	6.5	6	5	4.5	4.5	6	8	12.5	12	11.5	10	4.5	3.5	–	–	–	–
38°	6.5	4.5	4	2.5	3	4.5	5 5	9	10	10.5	10	6	4.5	2	0.5	–	–	–	–
37°	4	1.5	4	5.5	7	7	5.5	6	8	8	6.5	3.5	0.5	–	–	–	–	–	–
36°	3	3	4.5	5 5	5	6.5	7.5	6.5	6	5.5	3	0.5	–	–	–	–	–	–	–
35°	3.5	3	4.5	4.5	7	6.5	6.5	7.5	6.5	6	1	1	–	–	–	–	–	–	–
34°	5	6.5	8	8	7.5	5.5	7	7	5.5	3	–	–	–	–	–	–	–	–	–
33°	6.5	7.5	8	8.5	9	7	6	3.5	2	1	–	–	–	–	–	–	–	–	–
32°	6.5	5	6	6.5	6.5	5	2.5	1	1	–	–	–	–	–	–	–	–	–	–
31°	8	7.5	8	6.5	4	3.5	0.5	0.5	-	–	–	–	–	–	–	–	–	–	–
30°	4.5	5.5	4.5	4	2.5	1.5	–	–	–	–	–	–	–	–	–	–	–	–	–
29°	6	4.5	2	1.5	1	1 5	–	–	–	–	–	–	–	–	–	–	–	–	–
28°	3.5	2	1.5	0 5	0.5	1	–	–	–	–	–	–	–	–	–	–	–	–	–
27°	1	1	0.5	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
26°	1	1.5	1.5	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25°	0.5	1	1.5	1.5	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24°	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23°	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22°	–	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
21°	1	1	1	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20°	1	1	1	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–

ACH QUADRANGULAR DEGREE IN ONE YEAR, DEDUCED FROM THE AV
MARCH, 1871, TO FEBRUARY, 1873, INCLUSIVE.

LONGITUDE WEST FROM GREENWICH.

8°	87°	86°	85°	84°	83°	82°	81°	80°	79°	78°	77°	76°	75°	74°	73°	72°	71°	70°
.5	7.5	6	5	6	4 5	4.5	3.5	5	5	5	5	3.5	2	2	2	2.5	1	1.5
.5	17	15.5	15	11.5	10	10.5	8 5	7.5	7	6.5	7	6	4.5	4.5	4	5.5	5	5.5
	19.5	18.5	18	16.5	16.5	18	18	14.5	14	15	15.5	17.5	17.5	14	12.5	15	16	14.5
	14.5	18	17.5	17 5	20	21.5	18.5	20	21	22	21	20 5	20.5	24	22	24	26	24
.5	14.5	15	21	23.5	21	21.5	21.5	24	21	20.5	23.5	24	21.5	21.5	22.5	23.5	24	19
	14.5	14.5	15.5	19	18.5	18	20.5	22	21	20.5	23	21.5	22	21	22	15.5	15.5	16.5
	7	8.5	11	11	14	13	13	16	19	20.5	18.5	18	16	16.5	14	15	14	14
	6.5	7.5	9	9	8.5	10	12.5	12.5	11	12	12 5	13.5	12.5	10.5	12	13.5	12.5	13
.5	8	10.5	10	10.5	10	9	8	7.5	8.5	9.5	9.5	9.5	7	6 5	8.5	10	12	12
	11.5	9.5	6.5	5.5	5.5	5	5.5	5.5	6.5	4.5	4	3.5	4	4	8	10.5	12.5	13
	7	9	6	7	5	6.5	7.5	6	6.5	6	5	4.5	4.5	6	8	12.5	12	11.5
	6.5	6	8	6	5.5	7.5	6.5	4.5	4	2.5	3	4.5	5 5	9	10	10.5	10	6
	6.5	5	5.5	5	3	3.5	4	1.5	4	5.5	7	7	5.5	6	8	8	6.5	3.5
.5	3	3.5	3	3.5	4 5	4.5	3	3	4.5	5.5	5	6.5	7.5	6.5	6	5.5	3	0.5
	1	1	1.5	2	3.5	3.5	3.5	3	4.5	4.5	7	6.5	6.5	7.5	6.5	6	1	1
	1	2	2	1.5	1.5	4	5	6.5	8	8	7.5	5.5	7	7	5.5	3	–	–
.5	1	2	2.5	2	2.5	5	6.5	7.5	8	8.5	9	7	6	3.5	2	1	–	–
.5	3	4	4	3	4	7.5	6.5	5	6	6.5	6.5	5	2.5	1	1	–	–	–
.5	5.5	4	5	3.5	4.5	7	8	7.5	8	6.5	4	3.5	0.5	0.5	–	–	–	–
.5	4	2	3	4	6	6	4.5	5.5	4.5	4	2.5	1.5	–	–	–	–	–	–
5	4	3.5	5	5.5	6	4.5	6	4.5	2	1.5	1	1.5	–	–	–	–	–	–
.5	5.5	6	8	6.5	5.5	4.5	3.5	2	1.5	0 5	0.5	1	–	–	–	–	–	–
	5	5.5	6	2	1.5	1	1	1	0.5	0	0	–	–	–	–	–	–	–
.5	3.5	2.5	2	0.5	0	1	1	1.5	1.5	1	0	–	–	–	–	–	–	–
	1 5	2	2	0 5	0	0	0.5	1	1.5	1.5	0	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0	0	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	1	1	1	1	1	–	–	–	–	–	–	–
–	–	–	–	–	–	–	1	1	1	1	1	–	–	–	–	–	–	–

THE AVERAGE OF THE TWO

71°	70°	69°	68°	67°	66°	65°	64°	63°
1	1.5	2.5	1.5	3.5	4	1	1	–
5	5.5	7.5	9-5	14	10	6.5	4	–
16	14.5	17	18	16	11	9.5	7.5	–
26	24	22	16 5	12.5	9.5	6.5	4.5	–
24	19	18	19 5	15.5	12	9.5	5.5	–
15.5	16.5	16.5	14.5	17.5	19	12	6.5	4
14	14	17	18.5	20.5	18.5	14.5	6.5	3
12.5	13	18.5	20.5	16.5	14	9.5	3.5	1
12	12	12	14	12	8	4.5	2.5	–
12.5	13	10.5	11.5	6 5	2.5	2.5	1	–
12	11.5	10	4.5	3.5	–	–	–	–
10	6	4.5	2	0.5	–	–	–	–
6.5	3.5	0.5	–	–	–	–	–	–
3	0.5	–	–	–	–	–	–	–
1	1	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–
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–	–	–	–	–	–	–	–	–
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of Relative Storm Frequency, Professional Papers of the S. S., No. XIV., Washington, 1884," and subsequently in his "Sailors' Hand Book of Storm Track, Fog and Ice Charts of the North Atlantic Ocean," Boston, 1889, were based upon the same methods of procedure as my own, and the results are therefore comparable except only that his charts are based upon all the data available to him up to 1886, while my own are restricted to the use of the tri-daily Signal Service charts from March, 1871, to February, 1873, inclusive. My map of storm frequency was compiled by first collecting upon a few charts the complete tracks of all cyclonic storms except thunderstorms and tornadoes, which tracks could, of course, be plotted quite correctly because the location of the storm centre was given at regular eight-hour intervals. Assuming that these cyclonic storm centres had a central barometric depression of fifty miles diameter, it was easy to count how many such tracks passed over, or within twenty-five miles of, any point on the map. Strictly speaking, such points or elementary areas should have been small circles, but it was far more convenient to adopt the quadrangular areas bounded by successive degrees of longitude and latitude. These quadrangular areas grow smaller as we approach the pole, and the average number of storm tracks that cross any such area should apparently be corrected for latitude before we can obtain strictly comparable figures of relative frequency; but such correction was not made in compiling the published chart No. VI., which therefore shows the actual frequency per quadrangular degree and not the relative frequency per standard square degree. By a simple system of shading, the chart showed the average annual number of storm centres for six grades of frequency, viz., less than five at one extreme, over 22.5 at the other extreme. In those years I thought that the chart brought out very clearly the fact that the storm tracks, which move from Alberta and Assinniboin southeastward over the United States and then turn northeastward toward the Gulf of St. Lawrence, describe a system of parabolic curves whose tendency is to have a common point of intersection in Nebraska. But the subsequent greater accumulation of data will probably now show that this point of intersection, and therefore a region of maximum storm frequency, lies further to the northwest.

In order that the data on which chart No. VI. was based may

become accessible to meteorologists I have, with the permission of the Chief of the Weather Bureau, copied the accompanying table VII from my report of Dec. 18, 1873. In this table the vertical and horizontal lines represent meridians and parallels, and the figures opposite a given latitude and under a given longitude give the average annual number of storm centres passing over the quadrangle enclosed between that latitude and the one above it, and between that longitude and the one to the west of it. For the convenience of those who wish to make the correction for latitude, I have added on the left hand side the factor which, multiplied into the figures on the corresponding line, will give the number of storms passing over the equivalent square degree of a great circle. In using this factor the student should remember that there is still a correction which may be appreciable, due to the fact that the storm tracks do not strike the quadrangular areas at all times from the same azimuth. The secant factor here given assumes that the storm track approaches from the due north or south, whereas the factor would be uniformly unity if the storms approached from the due west or east. The truth, of course, lies between these two extremes; and for some purposes we should do best to use the factor unity as was done by me.

Washington, Feb. 19, 1893.

COLORED CLOUDY CONDENSATION AS DEPENDING ON AIR TEMPERATURE AND DUST-CONTENTS, WITH A VIEW TO DUST-COUNTING.*

PROF. CARL BARUS.

1. *Introductory.* — Mr. John Aitken, who has pioneered the meteorology of dust to a point of formidable importance, describes two distinct forms of apparatus for the quantitative measurement of the dust-contents of atmospheric air. The first of these is his well-known "dust-counter."† It has been widely used both

* Communicated by permission of the Chief of the Weather Bureau. Cuts kindly loaned by the courtesy of the Bureau.

† Aitken: Trans. Royal Soc. Edinburgh, xxxv., part 1, 1888; *ibid.*, xxxvii., part 1, No. 3, 1892; Proc. Roy. Soc. Edinburgh, xvi., p. 135, 1889 (containing full descriptions); *ibid.*, xviii., p. 259, 1890, '91; Nature: xxxvii., p. 428, 1888; *ibid.*, xli., p. 394, 1890; *ibid.*, xliv., p. 279, 1891; *ibid.*, xlv., p. 299, 1892, and elsewhere.

by himself and others and needs no comment here. Its trustworthiness seems assured, both in view of the elementary principles on which it is directly based, and of the consistency of the results obtained. In one respect this dust-counter is unique; for it probably takes account of all the particles, large or small, present in the given volume of air. At least it does not overlook the larger particles. In indirect dust-counters (Mr. Aitken's "koniscope" and the apparatus of the present paper being referred to), only a certain range of dimensions of water globules is visible, and it does not follow that all the dust present is contained in the optically active corpuscles. The restricted use of koniscopes is not necessarily a disadvantage; for the particles counted may be the very ones of interest. Indeed the whole question resolves itself into the character of the problem to be answered.

At the outset, therefore, it does not seem obvious that the indications of the two classes of instruments need necessarily be identical, and a calibration of one in terms of the other is to be made cautiously, so long as certain grades of dust are optically less active than others.

In the "koniscope" Mr. Aitken* has endeavored to express the dust-contents of a given sample of air, in terms of the color, or of the intensity of color, or of the amount of exhaustion necessary to produce a given color, when the cloudy condensation is produced by sudden expansion of the gas in a suitable tube, containing enough moisture to saturate the air. The importance of temperature is pointed out, but not evaluated. Mr. Aitken prefers to make the estimation in terms of the color-intensity of the blue, and the apparatus is graduated by comparing it with the direct dust-counter. Based as this apparatus is on color discriminations, it is not adapted to give more than a few steps of dustiness, and Mr. Aitken chiefly recommends it for qualitative purposes, such, for instance, as may present themselves in sanitary work.

2. During the course of my experiments on the thermal distribution in steam jets, I had frequent occasion to note the actuating steam pressure, at which the intense blue-violet field of my color tube merges into opaque, eventually to reappear (pres-

* Aitken: Proc. Roy. Soc. Edinburgh, li., p. 425, *et seq.*, 1892.

sure increasing) as an orange-brown field of the first order. It struck me that here was a sufficiently sharp criterion for fixing a value of pressure depending in the given apparatus only on the temperature, and the dust-contents of the inflowing air. In other words, for a given kind of air and at a given temperature, there are two well-defined pressures at which color (blue and yellow) vanishes into blackness. If the kind of air remains the same while its temperature varies, the paired values of pressure will also vary markedly, so that the margins of the opaque field may be mapped out in a diagram in which pressure is expressed in its dependence on temperature. It is the chief purpose of the present paper to show the character of this diagram, and to indicate the manner in which the positions of the loci vary, when the dust-contents of the inflowing air are also varied. Incidentally I will endeavor to ascertain the more immediate cause of the opaque field, and to see whether the water molecules may not themselves become nuclei of condensation. § 15.

3. *Apparatus.* — A full account of the necessary apparatus is given in figure 1, where the color tube is shown at *AA*, and the method of varying the temperature and dustiness of the inflowing air is shown at *E*, *D*, *F*. The color tube is identical in form with the apparatus described in an earlier paper.* I need only call to mind here that the steam issues at the jet *j*, from a nozzle about .16 cm. ($\frac{1}{16}$ inch) in diameter, and that the tube *AA* is about 50 to 60 cm. long, and in common with the air hole *C*, about 5 cm. (2 inches) in diameter. The glass plates *g* and *a* are kept clear by moistening with a solution of caustic potash, and the mirror *M* reflects skylight through the tube. Mixed steam and air escape at *B*, and provision is made (not shown) for screening off extraneous light from *g*, the window through which the color observations are made.

The two essential appurtenances are the thermometer *t*, to register the temperature of the inflowing air at *C*, and the open mercury manometer (not shown) by which the pressure of the steam entering the jet *j* is measured. Inasmuch as a mercury thermometer is not very quick in its indications, the air at a given temperature must be allowed to pass over the bulb of *t* for some time before the record is taken.

* Barus: Amer. Meteorolog. Journal, ix., p. 488, 1893.

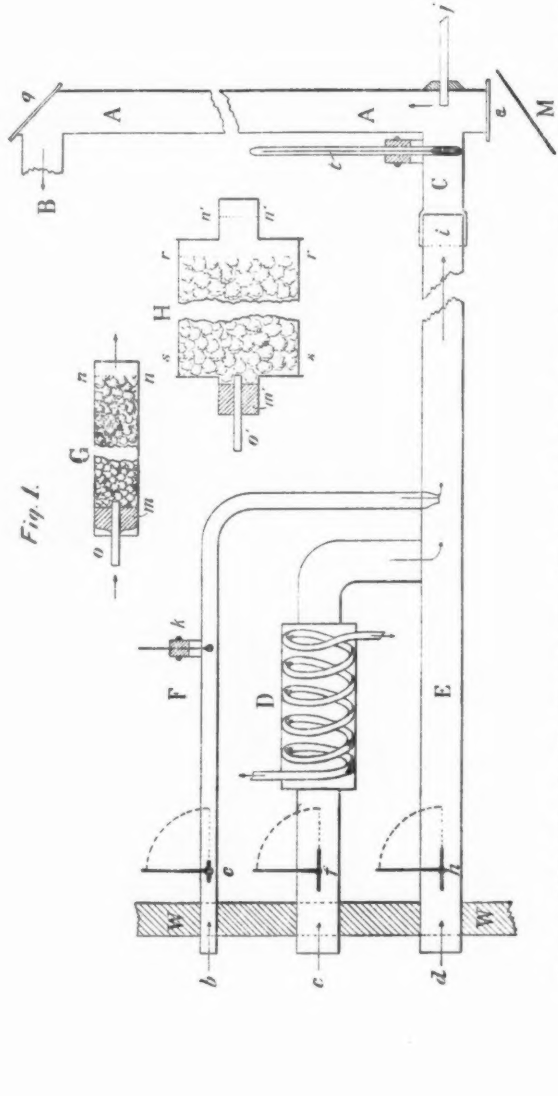


FIG. 1.—Color tube *AA*, with attached heater *ED*, duster *F*, and other appurtenances. *G* and *H*, filters. Sectional elevation. Diagram.

The steam used was generated in a copper globe about 25 cm. in diameter, and provided with a water gauge and a steam gauge. The vessel is heated by a large ring burner* and is strong enough to withstand say ten atmospheres, though in the present work pressures below two atmospheres fully suffice.

G and *H* are forms of air filters, to be described in § 14.

4. The air entering *C* is taken out of the atmosphere, the three influx tubes *E, D, F* passing through the window frame *WW* and opening into the air on the outside, as shown at *b, c, d.* Valves are inserted into each of these tubes at *e, f, h,* so that the quantity of air passing through any one of them may be regulated or even quite shut off. In the winter, when the valves are open, the air rushes through the tubes with considerable velocity, even when the jet *j* is not in action. This velocity increases with the steam pressure actuating the jet, but can be regulated by shutting off the valves *e, f, h,* partially.

The tube *E* is clear, and the air passing through it has the temperature of the atmosphere. The tube *D* discharges into *E* and is provided with a drum, containing a coil of thin lead pipe of about 0.6 cm. (¼ inch) calibre. About 20 turns of pipe, each somewhat less than 5 cm. in diameter, in a drum 35 cm. long and somewhat less than 10 cm. in diameter, are more than sufficient. In the winter time steam is passed through the lead pipe. Hence by suitably regulating the valves *h* and *f*, the air flowing through *C* may be kept at any desirable temperature; and as temperatures between 9° and 40° only are needed for the present purposes, this arrangement is quite satisfactory. In the summer time chilled brine or an expanding gas circulating through the coil will probably be serviceable.

The tube *F* also discharges into *E*, and is useful for increasing the dust-contents of the air entering *C*. For this purpose a little closed basket of wire gauze, attached to a stem passing through a perforated cork, is inserted into the tubulure *k*, as shown in the figure. A piece of phosphorus is put into the basket. The dusty exhalation of a freshly cut surface of phosphorus is almost *nil* at 0° C., but increases with great rapidity when the temperature rises. § 26. At any given temperature above 15° its dust supply is nearly constant for a long period of

* This apparatus used for other purposes is shown in Bulletin U. S. Geolog. Survey, No. 54, p. 60, 1889.

time (hours); hence its availability in the present work, unless the weather is very cold. Fortunately cold temperatures can usually be dispensed with when artificially dusty air is examined.

It is to be noted that all the tubes *E*, *D*, *F* must pass out of the room. If, for instance, *b* opened into the room (which would often be desirable for the reasons just mentioned), then if the jet is not in action or only slightly in action, cold air would pass into *C* and *D*, and out at *b* as well as at *B* into the room. At low steam pressure, the flow of dusty air would, therefore, necessarily be irregular. An advantage is secured by making the common tube *i C* long, so that the air may be well mixed before impinging upon the jet. At best, however, air dusted in this way is an inferior substitute for atmospheric air, and the results show much more fluctuation. Each of the valves, *h*, *f*, *e*, is provided with a suitable dial and an index. The valve *e* must be free from leaks. It is best, moreover, when atmospheric air is examined to remove the basket *k* altogether, and to close the hole with a cork. The hole through which *F* discharges into *E* need not be more than 0.5 cm. ($\frac{1}{4}$ inch, say) in diameter, and it is advisable to carry it into the axis of *E* by aid of a glass tube. The whole train of tubes is easily made of ordinary tinned drain pipe and suitable elbows. To summarize: the faint phosphorescent glow visible on phosphorus in the dark is a nearly permanent dust producer. This phosphorus-tainted air, discharged through a $\frac{1}{4}$ inch to $\frac{1}{8}$ inch tube into the 2-inch tube of pure air, usually produces persistent color effects at ordinary temperatures. Thus the dilution is less than $\frac{1}{100}$.

5. A few remarks on the shortcomings of the apparatus may be made here. It is clear in the first place that the temperature of the air entering *C* will vary with the intensity of the jet, *i. e.*, the velocity of current, even if the other adjustments remain unaltered. For, the more rapidly the air passes through the drum *D*, the less it is heated. This, however, is no serious inconvenience since temperature is measured at *t*.

Similarly the amount of dust introduced into the air will (probably) depend on the rate at which the current passes the basket at *k*. Hence at great jet intensities the air will be less dusty than for small intensities. I have found no easy way by which this discrepancy can be evaluated; and my experiments with artificially dusted air are intended rather to show the char-

acter of the dust variation than to map out precise loci. §§ 11-13. Fortunately the dust effect is so striking that there is no possibility of misinterpretation. Experiments which I made by introducing dust with jet pumps and aspirators showed no advantages. To vary the dust contents uniformly at all jet pressures, the mouths *c*, *d* of the air tubes must be introduced into a large artificially dusted room, instead of the atmosphere. But this method also presents grave difficulties. The final resort seems to be to examine the atmosphere at different times and in different places, or to construct apparatus for the rapid filtration of air. §§ 14, 15.

One serious theoretical question may be referred to here. It is necessary that at all steam pressures the amount of air entering *C* should be nearly proportioned to the amount of issuing steam. No doubt this is nearly the case; for not only do the air and steam currents increase and decrease together, but the air is admitted *in excess* of the quantity necessary to produce condensation at the supersaturated parts of the jet, and it is to this condensation that the color indications apply. If the valve *e* be closed, and the valves *f* and *h* all but closed, the pressures at which the margin of the opaque zone appears from blue increases; but the temperature registered at *t* also increases at even a greater relative rate, so that the apparent effect is curiously enough rather an excess than a deficiency of dust. § 13.

I infer from this that in the work below the air is always admitted in quantity sufficient to produce its maximum dust effect. To test this question preliminarily, I replaced the 0.16 cm. nozzle by another 0.09 cm. in diameter, and thus (*caet. par.*) only discharging $\frac{1}{3}$ as much steam as the former. The new results virtually coincided with the old (§ 15); and hence, though the relations below were obtained from a given apparatus, they are probably true generally* so long as the inflowing air exceeds a certain minimum quantity. A full discussion of all these points will be in order when I come to measure the thermal distribution within the color tube and particularly in the neighborhood of the nozzle of the jet. I will then show to what extent each jet

* It will be expedient to consider the small differential effect of variations of the barometer, and the tendency of the pressure (blue-opaque) to fall with the time of efflux, elsewhere.

possesses special hydraulic properties, depending on the degree of smoothness of bore.

The fact that pin-hole jets are quite sufficient makes the practical construction of the apparatus, Fig. 1, on a small scale, an easy possibility. A globular copper boiler, 5 inches in diameter, and a sensitive steam gauge with a capacity of less than 15 pounds are available for generating the steam and recording pressure.

6. *Results. Normal Atmosphere.* — The results in hand are necessarily in very great number, for the case is one in which the observer has to construct the mean value or path, when the observations themselves are unavoidably discrepant. It will therefore be expedient to avoid cumbersome tables, by expressing all the data graphically. An ulterior advantage is gained in this way, inasmuch as the broad features of the phenomena are at once evident to the eye.

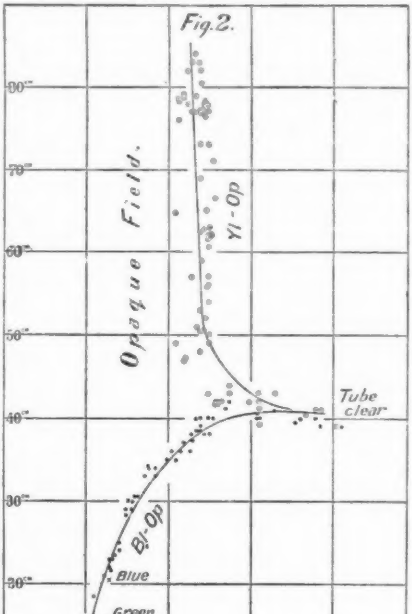


FIG. 2. — Chart showing the margins of the opaque field in terms of the actuating steam pressure and the air temperature.

In the chart, Fig. 2 (and in all succeeding charts), the abscissas indicate the temperature, in degrees C., of the air entering the color tube at C (Fig. 1); or, in other words, the registry of the thermometer t. The ordinates show the pressures in cm. of mercury, under which the steam is forced out of the jet. The points of the curve between 0 and about 40 cm. then

show the corresponding values of air temperature and steam pressure, at which the blue-violet (first order) field seen in the color tube merges into opaque. The points of the curve lying quite above 40 cm. show the conditions at which the brown-yellows of the first order just emerge from the opaque. Curves indicating the approximate loci are drawn through the points.

Below about 9° C., therefore, the field is opaque at all pressures above 9°; the pressure at which blue changes into opaque rapidly increases with increasing temperature; and the pressure at which brown-yellow changes to opaque decreases from an enormous value, and at even a more rapid rate as temperature increases. Both loci, curving at a gradually retarded rate, eventually reach a common asymptote at about 41 cm. (temperature being indefinitely high). At the same time the colors which were very intense at the lower temperature gradually become fainter, and the opaque zone more translucent, until at about 40° of air temperature (depending on the size of the nozzle, §15), the field is clear and without color. The escaping steam is gaseous and not visibly condensed. When temperature decreases again from 40°, white-yellow is the first color to appear, showing that the particles here must be the smallest of the whole series. At 35° the change from faint yellowish tones to faint white-blues, when pressure is made to vary suitably (see chart) from larger to smaller values, is quite marked. There is no opaque demarcation, however, but rather a mixture of colors, for the opaque field is hardly impervious to light above 30°. Indeed one often notices a brownish field surrounding the jet, on a violet-bluish ground.

For all temperatures and pressures lying to the left of the two curves the field is opaque, and it sends off a kind of cusp to penetrate into higher temperatures. There is a characteristic difference between the contours of the two margins; for whereas yellow-opaque after a sharp inflection shoots up almost vertically, blue-opaque shows a regular change of curvature throughout.

At about 13° in the chart, I have inscribed the approximate positions of the successive interference colors,* indicating their positions by a cross. This cannot be nearly so well done as the location of the opaque margin, and as the colors are of

* See Barus: Am. Met. Journ., ix., p. 500 *et seq.*, 1893.

smaller interest in the present paper, I will not enter into the subject further. The contour of the successive color curves is easily surmised from the line for blue opaque. Similarly above the yellow opaque line, a family of browns, oranges, and yellows may be located.

When the dust contents are increased, the margin of the opaque field approaches the abscissa, and hence the color loci will be successively more crowded together.

In the chart, Fig. 2, only a single air tube (*D*, Fig. 1) was available. The air was heated to about 40° by the circulating steam. This was then shut off and the temperature and pressure at which the colors disappeared noted on cooling. The mercury thermometer is scarcely sensitive enough for such observations, and the temperatures of the diagram are probably too high. I have, therefore, lumped all my observations between Feb. 10 and 23, 1893, in this chart, seeing that the phenomenon as a whole is well represented.

7. In the following work, however, the apparatus, Fig. 1, was used, with the phosphorus tube closed up and the phosphorus removed. Great care was taken to wait for stationary temperatures, and about five (or more) steps between 10° C. and 40° C. were selected for observation.

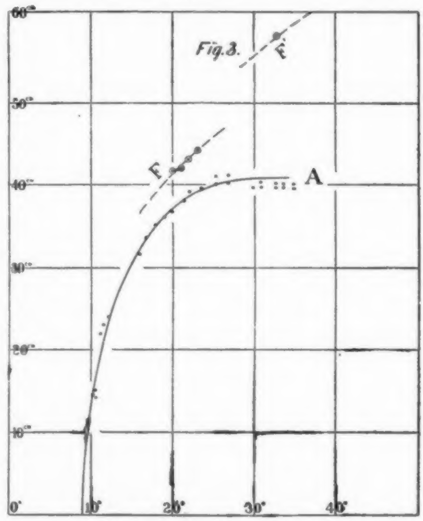


FIG. 3.— Chart showing the margins of the opaque field in terms of the actuating steam pressure and the air temperature.

The first set of experiments was made on Feb. 23, the chart,* Fig. 3, curve *A* being obtained in the morning, and Fig. 4 in the afternoon. The day was cold, with snow covering the ground.

* The observations *F F'* in Fig. 3 refer to filtered air and will be described in § 14.

The blue-opaque curve, *A*, Fig. 3, virtually reproduces Fig. 2; but the curve Fig. 4 differs from it inasmuch as the tangential angles in the latter case are steeper, so that the locus is less curved and rises higher than in Figs. 2 or 3. In all cases yellow-opaque lies above blue-opaque. I was at first inclined to refer this to differences of the vanishing standard, believing the two curves to contain consistent observations, but differing from each other for reasons purely subjective. Whether or not this is the case can only be found by comparison with succeeding series of observations as will presently be seen. Taking the observations at their face value the indication is less dust for the afternoon than for the morning. The curve *P* found for artificially dusty air will be described below. § 11.

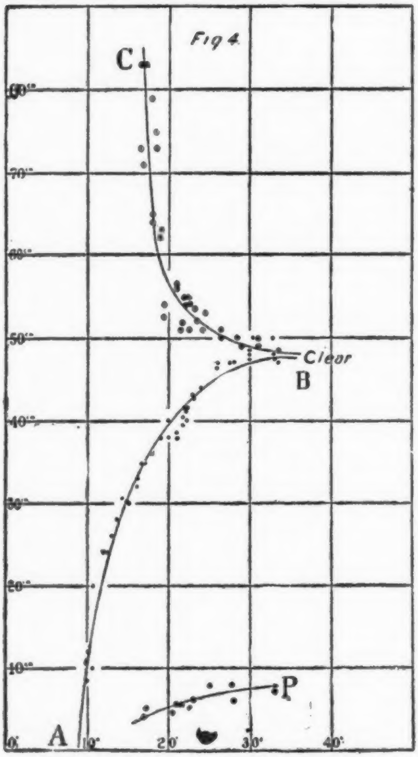


FIG. 4. — Chart showing the margins of the opaque field in terms of the actuating steam pressure and the air temperature.

8. The next series of observations were made on Feb. 27 (cloudy), 28 (rain), and on March 2 (clear). There was but little difference in the respective loci of the data except that on the latter day the asymptote was somewhat below the position for the other days (see chart Fig. 5). The common asymptote takes a mean position (pressure, $p = 43$ cm.) between the corresponding values of Figs. 2 and 3 ($p = 42$ cm.) and Fig. 4 ($p = 48$ cm.).

9. On March 3, however (see Fig. 6), the asymptote rose again to the value of about $p = 46$ cm. The data here are not

quite so uniform as in Figs. 2–5, but the locus is none the less outspoken. The weather was cloudy, antedating the storm of March 4. Two series of observations were made. The prevailing

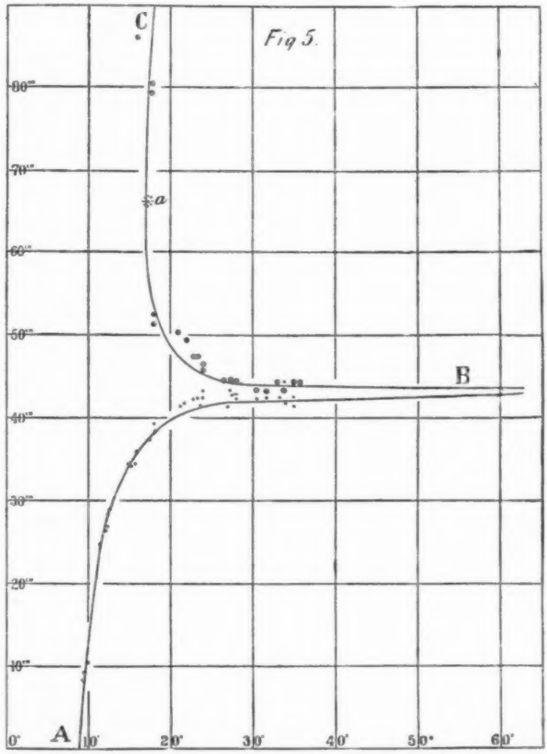


FIG. 5. — Chart showing the margins of the opaque field in terms of the actuating steam pressure and the air temperature.

warm weather prevented my taking observations at low temperatures. These new results induced me to conclude that the observations of Figs. 3 and 4 might very well correspond to different states of the atmosphere.

Finally, Fig. 7 contains the results of March 6, 8, and 10, agreeing in character with Fig. 5; while during the intermediate date, March 7, the locus fell to the lower position shown in Fig. 8. These figures as a whole afford strong evidence of the

oscillation of the asymptote with the dust-contents of atmospheric air. The observed interval of oscillation is within about 8 cm. of mercury pressure, but usually much below this.

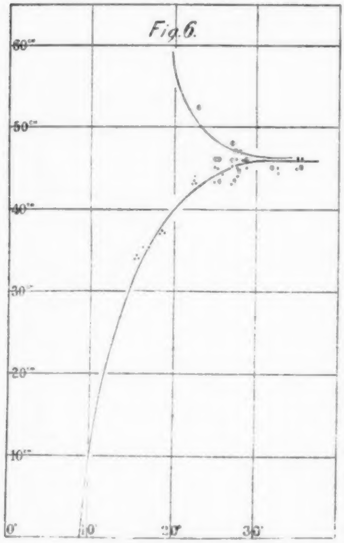


FIG. 6. — Chart showing the margins of the opaque field in terms of the actuating steam pressure and the air temperature.

10. *General character of the loci.* — Resuming the remarks of § 6, it is seen that when the asymptotes are high, the loci as a whole show less curvature and the points between 20° and 30° C. tend to fall below the corresponding points for low asymptotes. I have endeavored to bring the whole phenomenon into a convenient equation, in which temperature and dust-contents might appear as two variables by which the contours (pressure) of the margin of the opaque field (Figs. 2 *et seq.*), are conditioned. The invention of a single form in which both the blue-opaque and the yellow-opaque margins are contained is more difficult than the fitting of a separate form for each curve, and possibly I have not been fully successful in any case. Cumbersome equations, or such as lead to involved computations, are of little interest for the present purposes, where the object sought is merely a terse and convenient epitome of the very large number of isolated observations which go to make up each of the curves in question.

I will here omit the earlier hyperbolic and exponential forms each of which brought out some particular feature of the curves, and merely state a general form which (all things considered) probably reproduces my results within the limits of error.

Let p be the steam pressure actuating the jet, and t the temperature of the air into which the jet is discharged, and let A, B, C, n be constants to be presently discussed. Then

$$t = A\ 10^{\frac{Cp}{(p-B)^n}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (1)$$

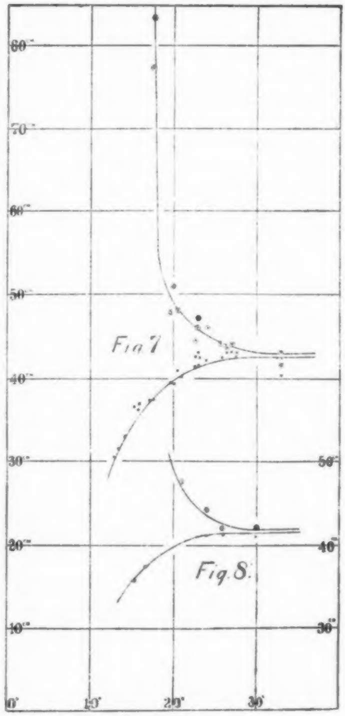
The quantity $(p-B)$ in (1) is always to be taken as a numeric, *i. e.*, positively; otherwise imaginary results are encountered. Suppose now this equation is tested by the data of Fig. 5, as these fairly represent a mean case. Then

$p=0$, $t=A=9$, by observation;

$p=B$, $t=\infty$, or $B=43$, the height of the asymptote above the abscissa;

$p=\infty$, $t=\infty$.

Hence the yellow-opaque margin, lying quite above $p=B=43$, corresponds directly to equation (1); whereas the blue-opaque margin, lying quite below $p=B=43$, corresponds to (1) with $(p-B)$ replaced by $(B-p)$. Furthermore, while in the yellow-opaque branch p increases from 43 cm. to ∞, t passes through a minimum value. It is, therefore, necessary to inquire the position and character of this singular point. Let equation (1) be differentiated, remembering that $t=0$ corresponds to $p=-\infty$, and therefore does not enter the present problem, and that $B=p$ has already been disposed of. Then the pressure p_m, corresponding to the minimum temperature t^m in question, is found to be



FIGS. 7 and 8.—Charts showing the margins of the opaque field in terms of the actuating steam pressure and the air temperature.

$$p_m = \frac{B}{1-n},$$

and the somewhat more involved expression of t_m is found from equation (1).

With these preliminaries, the remaining constants C and n are then easily enough though somewhat tediously obtained from

the observations making up Fig. 5, by trial. The results are as follows : —

$$A = 9\,;\ C = 0.013\,;\ n = 0.35\,;\ B = 43.$$

Steam-pressures, p, in cm. of mercury ; air-temperatures, t, in degrees C.

$p =$ 0 cm.	$t =$ 9.0°	$p =$ 43 cm.	$t = +\infty$°
10	9.8	44	33.6
20	11.0	47	21.4
30	13.0	50	19.2
40	20.3	*66.2	*17.4
42	31.6	70	17.4
42.8	85.3	90	18.1
43	$+\infty$		
Blue-opaque.		Yellow-opaque.	

*Minimum.

This curve, equation (1), has been inscribed in Fig. 5, to show the grouping of the observations around it. The minimum is marked at a ($t_m = 17.4$°C., $p_m = 66.2$ cm.). Throughout the extent of the figure, it unites two sufficiently flat curves to fairly represent the observations ; for this part of the margin, from its exceedingly steep ascent, cannot be traced with precision.

As a whole, therefore, equation (1) has reproduced the complete phenomenon surprisingly well, both as regards the blue-opaque ($A\ B$) and the yellow-opaque ($B\ C$) margin of the opaque field. No doubt, better agreement could be had on further trial, particularly by varying the point of intersection with the abscissa, $t = A$. I shall not, however, do this here, since in the present paper the chief datum is the height of the common asymptote ($p = B$) above the abscissa. It is this parameter which expresses the dust-contents of the air, and which fortunately may be obtained without computation by the direct observations presently to be more fully specified.

11. *Artificially dusty atmospheres.* — To interpret the above data it is necessary to increase the dust-contents of the normal atmosphere artificially, utilizing the tube F, Fig. 1, containing phosphorus. The results for this case are not without complexity, but the character of the effect produced is obvious at once : it takes but a trace of phosphorous tainted air to make the field permanently opaque at all pressures and temperatures not unreasonably high. In other words the tendency is to drop the blue-

opaque curve of the above Figs. 2 to 8, into coincidence with the abscissa. One would surmise that at least the asymptotic portion of the yellow-opaque curve would likewise drop to the abscissa, and this is actually the case as will be shown presently. By allowing the discharge from *F* to take place into *E* through a glass tube, only 0.6 cm. (less than ¼ inch) in diameter, while the air tube *C* is fully two inches in diameter, I was able to dust the air sufficiently to obtain at least the approximate contours of the corresponding relation of steam-pressure and air-temperature. The data are inscribed in Fig. 4, and together they make up the curve *P* near the axis of temperature. Thus the striking potency of even traces of dust is well exhibited.

Clearly the rudimentary curve *P* is a member of the same family to which *A B* belongs, and it is, therefore, obvious that the whole vertical distance between *B* and the abscissa is a region of temperature and pressure loci, each of which corresponds to a particular value of dustiness. Since, therefore, the accuracy with which the point can be located at any (mean) temperature is about 1 cm., the apparatus ought to register about 40° of dust-contents between normal atmospheric air and the artificial mixture stated. On this scale the variation of the dust-contents of normal air lies in the interval between 40 cm. and 50 cm. of mercury, remembering that the height of the asymptote (virtually reached at 28° to 30°) is taken for registry.

12. To bring out the conditions more fully, however, it is necessary to make supplementary tests both with phosphorus and with filtered air.

If the basket of phosphorus is placed in the tube *E* (Fig. 1) near its mouth *d*, where the air temperature (in winter) is near the freezing point, no effect is produced. Thus at 21°–22° the blue-opaque margin was at 41–42 cm., showing that the oxidation at zero is relatively negligible in spite of the current of air.

If, however, the same phosphorus be placed in the tube *EC* at *i*, somewhere between the point of confluence and the color tube, and where the temperature is say 20°, then it is actually possible to obtain the yellow of the first order at steam pressures less than 1 cm. Thus at 19°, the yellow-opaque margin was at 1.2 cm., and the color persisted with increasing brilliancy at all pressures above this.

For temperatures greater than 20°, the tube is yellow at all pressures until eventually above 35° all color vanishes for want of supersaturation.

For temperatures below 20°, the tendency is to produce opaque fields. Thus at 15° the tube is opaque at all pressures above a few millimeters.

The explanation of this somewhat puzzling behavior is this: at any given admissible temperature, the effect of phosphorous dust is a change of the color of the field in the direction from blue through opaque to yellow in proportion as more dust is added. Again the dust-contents of the air passing over a given lump of phosphorus decreases both with the rapidity of the current and with the degree of cold. Hence at higher temperatures than 20° brilliant brown-yellow fields are the usual occurrence when the phosphorus lies in the air tube, *C*. If withdrawn from the air tube and so circumstanced that its exhalation is diluted with much air (tube *F*, Fig. 1), then any color may be produced, depending on the degree of dilution. On the other hand below 20°, the oxidation takes place more and more slowly, so that only very gentle currents of air can carry off enough dust to produce a yellow field. For strong currents in *C* there is a double source of dilution, and opaque fields are the rule. In other words the air now approaches the state *A B* in Fig. 4, so far as dust-contents are concerned.

I have entered this subject at length because of its important theoretical bearing, seeing that it is necessary to disentangle a series of involved relations.

13. In Fig. 9 (diagram), the pair of curves *ABC* indicates the margin of the opaque field for unusually pure atmospheric air. Above the horizontal asymptote through *B* there is a symmetrical disposition of browns, oranges, and yellows, the order of colors decreasing upward. Below *B* the colors are blues, greens, and hues of higher orders. The whole field to the right of *ABC* is colored, merging into colorless; the field to the left of *ABC* is opaque.

As the air becomes more and more dust-laden, the yellow territory encroaches on the blue, so that for unusually dusty atmospheric air the pair of curves *ABC* has changed into *ADC*.

In the same way the yellows will continue to advance upon the blues for each successive (now artificial) increment of the

dust-contents of the air, until eventually the blues have been quite crowded out of the field, and the whole territory is persistently yellow at all temperatures and pressures. In other

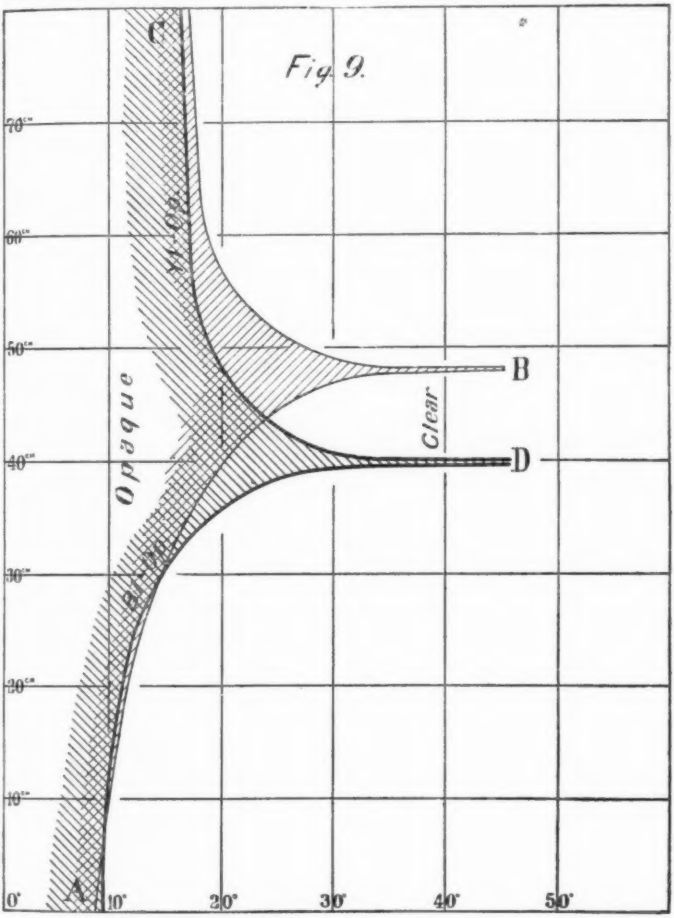


FIG. 9.—Variation of the opaque margin due to a change of dust-contents. Diagram.

words the asymptote of the curve descends with increasing dust-contents, while at the same time the curve *BC* moves bodily to the right, so that *BC* finally coincides with the co-ordinate axes of pressure and temperature. This at least is the essential

feature of the phenomenon so far as I now understand it. Subsidiary details will be brought forward at some other time.

It is to be remembered that the particular curves, Figs. 2 *et seq.*, apply primarily to the particular jet discharging into the given tubes. Nor can any attempt as yet be made to graduate the apparatus; for a comparison with the Aitken dust-counter (as has already been stated) is not legitimate, unless it can be proven that any given class of particles occurs proportionally to the total number, certainly a hazardous hypothesis. For the present the height of the curve above 28° (asymptote), expressed in centimeters of mercury pressure, is the empiric dust-indicator.

14. *Filtered Air.* — A grave difficulty is encountered in using filtered air, inasmuch as the supply cannot be obtained in sufficient quantity without employing very cumbersome apparatus. I have helped myself provisionally by using a tin tube *G*, Fig. 1, with the end *n n* large enough to fit snugly into the air hole *C* when the heater is removed. *G* is filled with cotton throughout about 20 cm. of its length in the usual way. The end *n n* is closed with a sieve of brass wire gauze, while the end *m* is closed with a perforated rubber cork, through which an influx tubulure, *o*, projects. This is connected with an ordinary oxygen tank, containing highly compressed air.

When the tube *C* (Fig. 1) is closed with the filter *G* (no gas passing through it), the field of *A A* at once becomes clear; at the same time, however, its temperature rises to the boiling point, and the absence of color in this case is as much the result of insufficient supersaturation as of absence of dust. Now let the compressed air be admitted, so that the tube *A A* is considerably cooled. If the steam pressure is high enough, and the gas in sufficient quantity, the field first clouds over and then turns quite opaque. Thus at a pressure of 50 cm. and a temperature registered at *t* of 47°, such a result (opaqueness) was obtained. At 30 cm. steam pressure, the field turned cloudy, but opaque; at 15 cm. no clouding was even apparent. Colors were not observed in any case.

In view of the insufficient air supply obtained in case of the filter *G*, I replaced it by the form *H*, differing from *G* in having a drum much larger in diameter (length 25 cm., diameter 15 cm.), and special sieves *r r* and *s s*. Similar parts are similarly

lettered. Under like conditions, such a filter should supply nine or more times as much air as the other (G).

The absorbent cotton inserted between the sieves $s\,s$ and $r\,r$ (the former and the lid being removed, and the latter [$r\,r$] soldered in place) was carefully laid in layers parallel to $r\,r$, quite filling the width of the drum. When full to the top, the cotton was compressed by the second sieve $s\,s$, which thereafter was also soldered in place, the lid with the inlet pipe $o'm$ soldered on, and the space between lid and $s\,s$ filled with loose cotton to catch dirt. The compressed charge between $s\,s$ and $r\,r$ mainly acts as the filter. When not in use it should be heated, so as to be thoroughly dry.

In the first experiments with the filter H, compressed air (issuing as usual from a narrow pipe, and at a tank pressure of about 15 atmospheres) was used as before. Spreading through the filter, the air enters the color tube at a much reduced velocity. As the air in the tank is gradually freed from dust by the subsidence of the latter, there is here an additional means of purification. But the method is much too lavish to be practical, even if it be conceded that the filter is actually efficient. The following data were thus oblained at temperatures comparable with the values in the charts. Colors were not observed: —

Temperature	20°	21°	22°	23°	33°	C.,
Pressure	41.5	42	43	44	58	Cm. Hg.

In the set of data for 20° to 23° the filter was not so well packed as at 33°. Observations were discontinued for want of gas. I have inserted these data in the chart, Fig. 3, at F and F^1. When taken together, they suggest a locus of the same nature as Fig. 4, *i. e.*, implying less curvature in proportion as the air is less dusty. Bearing this in mind, the margin of the opaque zone at 20° for filtered air is not as much above the atmospheric curve as one would anticipate. It follows that the size of the particles producing colored cloudy condensation in atmospheric air is not necessarily enormous when compared with molecular diameters, an inference which I have already drawn* both from the character of the color phenomena and from the conditions of condensation.

* Am. Met. Jour., ix., pp. 507, 519, 1893.

15. Having obtained these preliminary results, I attacked the subject on a much larger scale, using an apparatus very similar to Fig. 1 (with the phosphorus tube removed), except that the air, instead of being taken out of the atmosphere at *c* and *d*, passed at those points through two large filters of the type *H*, Fig. 1. A large Root blower actuated by a one horse-power gas engine forced the air through the system.

Contrary to my expectations this arrangement remained to the last utterly inefficient. When the blower acted under low pressures, the air entering the color tube was insufficient in quantity. For higher blower pressures and a more rapid current of air,* the evidences of filtration were practically absent. It was easy to trace the increase of dust-contents with the velocity of the current of nominally filtered air, even though high speeds were excluded by the nature of the case. The nozzle of the original steam jet being 0.16 cm. in diameter, I replaced it by a finer one, 0.09 cm. in diameter, but without advantage. It is noteworthy that for atmospheric air both these jets gave identical results as to the location of the opaque margin near the asymptote. The colors for the fine jet were fainter, and together with the opaque field vanished at a lower temperature, as one would suppose, seeing that only one third as much steam is available in one case as in the other.

The best results for filtered air are, therefore, those of the preceding paragraph. A sufficient degree of supersaturation presupposed, in no case was there an absence of condensation; but as I cannot assert that the air used was rigorously pure, it does not follow that I have reached the conditions † under which the molecules themselves act as condensation nuclei. Were this the case, then the supersaturation at the lower margin of the opaque field, expressed either isothermally as pressure or isopiestically as temperature, lead easily to the molecular dimension. For the margin in question is a locus at which the issuing steam

* Compare this with the similar experiences of Mr. Aitken, in Trans. Roy. Soc. Edinburgh, xxxv., p. 11 *et seq.*, 1888.

† The delicate question of purity comes into play in the other researches. Thus condensation apparently without nuclei was produced by Aitken (Trans. Roy. Soc. Edin., xxxv., p. 16, 1888), using the expansion method. R. v. Helmholtz failed to obtain it for exhaustions up to one-half atmosphere (Wied. Ann., xxvii., p. 521, 1886), whereas Aitken's exhaustions were only to three-fourths atmosphere (l. c. p. 8).

condenses as a whole, or in which the vapor contains within itself the conditions of condensation.

16. *Variation of the Dust-contents of normal air.* — In conclusion I shall summarize my results for the observed changes of the dust-contents of normal atmospheric air, expressing this datum by the height (steam pressure in cm. of mercury), of the asymptote of the margin of the opaque field, at a temperature near 30° C., of the inflowing air. The observations for earlier dates are necessarily somewhat crude and sporadic; for in work of this kind it is difficult to arrive at a fixed personal equation at once. The apparatus, moreover, was imperfect in one or more of its early details. The air taken in at the centre of the Smithsonian Park is probably as normally atmospheric as can be had in Washington.

TABLE I.

Dust contents on successive days: *i. e.*, pressures actuating a steam jet discharged into normal air, between 28° and 30°, when the blue color-field passes into opaque: —

Date.	Pressure.	Date.	Pressure.	Date.	Pressure.
1893.	Cm. Hg.	1893.	Cm, Hg.	1893.	Cm, Hg.
Before 23/2.	40	10/3, P. M.	42.5	18/3, A. M.	42
23/2, P. M.	48	11/3, A. M.	42	18/3, P. M.	41.5
24/2.	43.5	11/3, P. M.	42.5	19/3, A. M.	42
25/2.	43.5	12/3, A. M.	42	20/3, A. M.	42.5
27/2.	43	13/3, A. M.	43	20/3, P. M.	42
28/2.	43	13/3, P. M.	43.5	21/3, A. M.	42.0
2/3.	43.5	14/3, A. M.	43	21/3, P. M.	42.5
3/3.	46	14/3, P. M.	42	22/3, A. M.	41
6/3.	42	15/3, A. M.	42	22/3, P. M.	42
7/3.	42	16/3, A. M.	43.5	23/3, A. M.	41
8/3.	43	16/3, P. M.	43.5	24/3, A. M.	40.5
10/3, A. M.	43	17/3, A. M.	43	–	–

The results are shown graphically in Fig, 10, where the dates are laid off as abscissas, and the dust-contents (expressed in pressures as above) as ordinates.

The chart contains about a month's observing, and in its general features calls to mind Mr. Aitken's "dust-curves," remembering, however, that in Fig. 10 the ordinates grow with increasing purity. Throughout the month the dust-contents of

the air do not depart very often from their normal value, and the fluctuations are usually characterized by a suddenness (relatively speaking) of appearance. Thus marked changes of dust-contents may take place within fractions of a day. In

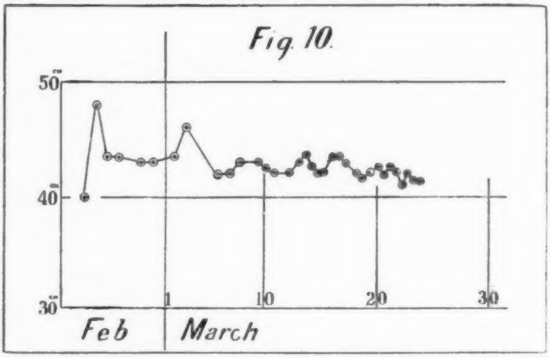


Fig. 10. — Diurnal variations of dust-contents (empirically rated) of normal atmospheric air.

general the air has been gradually getting less pure, between Feb. 23 and March 23.

I have endeavored to put these data into correspondence with the meteorological elements of the time of observation, and I have also availed myself of the comprehensive digest which my colleague, Prof. F. H. Bigelow, has constructed; but the time during which the above observations have been taken is as yet far too short to make such comparisons fruitful. The object of Fig. 10 is therefore rather to exhibit the character of the results obtained and the degree of efficiency of the above apparatus, than to attach any ulterior meaning to the results themselves.

Physical Laboratory, U. S. Weather Bureau.

SIX AND SEVEN DAY WEATHER PERIODICITIES.

H. HELM CLAYTON.

IN 1884 the writer began contributing to this JOURNAL evidences which he had found showing periodicities in the weather. He had been studying the subject for several years, and besides a periodicity of twenty-five months, called the editor's attention, in private talks, to what appeared convincing evidence of the frequent appearance of periodicities of about thirty days and seven days. To test with what accuracy such periodicities and the slow drifting of weather areas from west to east could be used in forecasting for long intervals in advance, Prof. Harrington, now Chief of the Weather Bureau, opened the pages of this JOURNAL, during the summer of 1885, to Mr. Sherman and the writer, to make forecasts for something over a month in advance. Besides general forecasts the writer made detailed forecasts for selected days. These detailed forecasts were based on a seven day periodicity, the evidences for which the writer published in this JOURNAL for August, 1885 (vol. II., page 162). In this JOURNAL for February, 1886 (vol. II., page 462), it was shown that these detailed forecasts for the three months they were continued averaged 80 per cent successful. In 1887 the trustees of the Elizabeth Thompson fund thought the evidences of this seven day period sufficiently important to grant the writer funds for further investigation, but the necessity of other work prevented his undertaking it. During the past winter Mr. W. H. Fergusson, under the writer's direction, began gathering data for the study of temperature changes at Blue Hill.

In order to eliminate the diurnal changes, the weekly thermograph curves obtained at the Blue Hill Base Station, during 1891 and 1892, were taken and treated by a method suggested by Prof. W. M. Davis. First a line was drawn through the maximum of each diurnal wave, then a line was drawn through the minimum, and finally a mean line was drawn half way between them as accurately as could be determined by the eye. Next were obtained the date and hour of these resulting temperature waves which may, perhaps, be called cyclonic and anticyclonic temper-

ature oscillations. This was done without any idea of their being used for a study of periodicity, and no changes have been made since, so there was no room for personal bias in determining the intervals between them. After the table was finished a vere striking regularity between the intervals of many of the maxima was noticed. This led the writer to investigate the subject, and he was surprised to find that almost all the maxima could be arranged in such a way that they followed each other at regular intervals, mostly at intervals of six or seven days. The dates and hours of the observed maxima arranged in this way are given in table No. I.* This table includes all the maxima, except two in 1891: one on Jan. 2, at 11 A. M., and one on Feb. 2, at 4 A. M. To save space, some of the May maxima in 1891 are recorded in Column II opposite September.

* This and the subsequent tables are taken from data prepared for publication in the *Annals* of *Harvard College Astronomical Observatory*.

TABLE I.

DATES AND HOURS OF TEMPERATURE MAXIMA.

1891.

COLUMN I.

Date.	Hour.	Interval. Days.	Interval. Hours.
Jan. 12	2 A.		
		6	+ 4
18	6 A.		
		6	+ 2
–	–		
		6	+ 3
30	11 A.		
Mean,		6	+ 3
Feb. 6	11 P.		
		6	+14
13	1 P.		
		6	− 1
–	–		
		6	− 2
25	10 A.		
		6	+ 8
Mar. 3	6 P.		
		6	+ 7
10	3 A.		
		6	+ 9
16	12 A.		
		6	+ 7
22	7 P.		
		6	+27
29	10 P.		
		6	−29
Apr. 3	5 A.		
Mean,		6	+ 4 ±10
Apr. 19	12 A.		
		7	+36
27	12 P.		
		7	−12
May 4	12 A.		
		7	− 6
11	6 A.		
		7	+ 7
18	1 P.		
		7	+35
26	12 P.		
		7	− 8
June 2	4 P.		
		7	0
–	–		
		7	0
16	3 P.		
		7	+ 1
23	4 P.		
Mean,		7	+ 6 ±15
July 13	7 P.		
		6	− 7
19	12 A.		
		6	+ 1
25	1 P.		
		6	+41
Aug. 2	6 A.		
		6	− 6
7	12 P.		
		6	−43
12	3 A.		
		6	+ 9
18	12 A.		
		6	+18
25	6 A.		
Mean,		6	+ 2 ±18

COLUMN II.

Date.	Hour.	Interval. Days.	Interval. Hours.
Jan. 16	10 A.		
		6	+ 7
22	5 P.		
		6	+ 2
–			
		6	+ 2
Feb. 3	8 P.		
		6	+15
10	11 A.		
		6	+13
16	12 P.		
		6	−22
22	2 A.		
		6	+20
28	10 P.		
		6	+12
Mar. –	–		
		6	+12
13	11 P.		
		6	−23
18	12 P.		
		6	+12
25	12 A.		
Mean,		6	+ 4 ±10
Apr. 14	12 A.		
Apr. 23	6 A.		
		7	+11
30	5 P.		
		7	+ 0
May –	–		
		7	+ 0
14	4 P.		
		7	+ 0
21	4 P.		
		7	− 4
28	12 A.		
		7	+ 3
June –	–		
		7	+ 3
11	6 P.		
		7	+ 7
–	–		
		7	+ 7
26	8 A.		
Mean,		7	+ 3 ± 6
July 4	10 P.		
		6	+ 8
11	6 A.		
–	–		
–	–		
29	7 A.		
Aug. 14	6 P.		
Aug. 22	1 P.		
		6	+ 1
28	2 P.		

TABLE I.—*Continued.*

DATES AND HOURS OF TEMPERATURE MAXIMA.

1891.

Column I. Date.	Hour.	Interval. Days.	Interval. Hours.	Column II. Date.	Hour.	Interval. Days.	Interval. Hours.
Sept. 4	9 A.						
–	–	{7	+ 2				
18	1 P.	7}	+ 2				
25	7 P.	7	+ 6				
Mean,		7	+ 3				
Sept. 25	7 P.			May 2	4 P.		
29	6 P.	4	− 1	9	3 A.	7	−13
Oct. 4	1 A.	4	+ 7	16	2 P.	7	+11
8	10 A.	4	+ 9	–	–	{7	+11
				31	12 A.	7}	+11
Mean,		4	+ 5 ± 4	Mean,		7	+ 5
Oct. 15	5 A.						
20	12 A.	5	+ 7				
26	8 A.	5	+20				
31	12 A.	5	+ 4				
Nov. 6	6 A.	5	+18				
11	11 A.	5	+15				
17	9 A.	5	+23				
23	1 P.	5	+28				
27	7 P.	5	−18				
Mean,		5	+11 ±11				
Dec. 7	12 A.			Dec. 10	4 P.		
14	12 A.	7	+ 0				
Dec. 16	9 A.						
23	2 P.	7	+ 5				
30	1 A.	7	−13				
Jan. 6	9 P.	7	+20	Jan. 2	4 P.		
14	3 P.	7	+16				
Mean,		7	+ 7 ±13				

TABLE I. — *Continued.*

1892.

Column I.				Column II.			
Date.	Hour.	Interval. Days.	Interval. Hours.	Date.	Hour.	Interval. Days.	Interval. Hours.
Jan. 19	3 A.	6	+10	Jan. 23	10 A.	6	+11
25	1 P.			29	9 P.		
Feb. 2	2 P.	6	+26				
9	4 P.	6	—10	Feb. 11	11 P.		
15	6 A.			–	–		
Mean,		6	+ 8	–	–		
			±18				
				29	10 P.		
Feb. 19	12 P.	6	+ 6				
26	6 A.						
Mar. 10	2 P.	8	+11				
19	1 A.	8	— 9	Mar. 26	4 P.		
28	4 P.	8	0				
Apr. 3	4 P			Apr. 6	4 P.		
Mean,		8	+ 1				
			± 7	8	3 P		
Apr. 23	1 A.	6	+ 3				
29	4 A.	6	— 6				
May 4	10 P.	6	— 5	May 2	12 A.	6	+ 5
10	5 P.			–	–	6	+ 5
Mean,		6	— 2	14	10 P.		
			± 4				
May 18	12 A.	7	— 8				
25	4 A.	7	+34				
June 2	2 P.	7	— 6				
9	9 A.						
Mean,		7	+ 7				
			±18				
June 6	4 P.	7	+28				
14	8 P.	7	+ 9				
22	5 A.	7	+13				
29	6 P.						
Mean,		7	+16				
			± 6				

TABLE I. — *Concluded.*

1892.

Column I. Date.	Hour.	Interval. Days.	Interval. Hours.	Column II. Date.	Hour.	Interval. Days.	Interval. Hours.
July 8	3 A			July 3	5 P.		
13	11 P.	6	− 4				
20	2 A.	6	+ 3				
26	12 A.	6	+10				
Mean,		6	+ 3				
			±15				
Aug. 4	6 P.						
11	2 P.	7	− 4				
19	1 A.	7	+11				
25	12 P.	7	− 2	Aug. 21	8 P.		
Mean,		7	+ 2				
			± 7				
Aug. 25	12 P.						
31	12 A.	5	+12				
5	10 P.	5	±10				
–	–	{5	− 6				
		{5	− 6				
14	9 A.						
19	12 A.	5	+ 3				
24	3 A.	5	− 9	Sept. 28	6 P.		
Mean,		5	+ 1				
			± 8				
Sept. 24	3 A.						
Oct. 1	3 A.	7	+ 0	Oct. 4	10 A.		
8	2 P.	7	+11	11	12 A.	7	+ 2
14	5 P.	7	−21	19	11 A.	7	+23
23	7 A.	7	+36	26	10 A.	7	− 1
30	6 A.	7	− 1	Mean,		7	+ 8
Mean,		7	+ 5				±10
			±15				
Oct. 30	6 A.						
Nov. 8	7 A.	9	+ 1				
18	5 A.	9	+22				
27	5 A.	9	+ 0				
Mean,		9	+ 8				
			±10				
Dec. 4	6 A.			Dec. 9	2 A.		
14	2 A.	9	+20	25	2 P.		

It is seen from this table that intervals of about six days prevail for some time, then the succession breaks and intervals of another length, usually about seven days, prevail for a while, etc. In several cases the six and seven day intervals were double, and in May, 1891, the seven day interval was treble for a while, that is, there were three maxima each week.

Though six and seven day intervals were the prevailing lengths, mean intervals of 4, 5, 8, or 9 days were obtained at times.

TABLE II.

MEAN INTERVALS BETWEEN TEMPERATURE MAXIMA.

Summary of Table I.

DURATION.	No. of Consec. Periods.	Mean Length of Period.				
1891.		d. h.	d. h.	d. h.	d. h.	d. h.
Jan. 12 to Apr. 3	9		6 4 ±10			
Apr. 19 to June 23	9			7 5 ±10		
July 4 to Aug. 25	7		6 2 ±18			
Sept. 4 to Sept. 25	3			7 3 ±		
Sept. 25 to Oct. 8	3	4 5 ± 4				
Oct. 15 to Nov. 27	8	5 11 ±11				
Dec. 7 to Jan. 14	4			7 7 ±13		
1892.						
Jan. 19 to Feb. 26	2		6 8 ±12			
Mar. 10 to Apr. 3	3				8 1 ± 7	
Apr. 23 to May 10	3		6 2 ± 4			
May 18 to June 29	3			7 7 ±18		
July 8 to July 26	3		6 3 ±15			
Aug. 4 to Aug. 25	3			7 2 ± 7		
Aug. 25 to Sept. 24	6	5 1 ± 8				
Sept. 24 to Oct. 30	5			7 5 ±15		
Oct. 30 to Dec. 14	3					9 8 ±10

Mean	6 3 ±12	7 5 ±11
Number of periods	24	27

These results are distinctly shown in Table II. It is found from this table that the mean length of the six day period is about six days and three hours, and the mean length of the seven day period is about seven days and five hours. The close agreement of the means of the six and seven day intervals at each separate reappearance renders it highly probable that these periods have constant lengths, and that the final means at the bottom of Table II. in each case cannot be very far from the true lengths.

In the column in Table II., giving the number of consecutive periods, the frequent repetition of the number three or some of its multiples suggested that there was some system in the curious alternation of the periods of different lengths. In order to ascertain, if possible, what this was, the dates between which the intervals changed from one length to another were tabulated as shown in table III.; and the mean dates of change thus obtained.

TABLE III.

Dates of Change in Period.	Mean Date.	Dates of a Twenty-Seven Day Period.		Numbers of Solar Rotations.
1891.				
Apr. 3 to Apr. 19	Apr. 11	Apr. 8		
		May 5		
		June 1		
June 23 to July 4	June 28	June 28		3
		25		
Aug. 25 to Sept. 4	Aug. 30		Aug. 30	$2\frac{1}{3}$
Sept. 25	Sept. 25		Sept. 26	1
Oct. 8 to Oct. 15	Oct. 11	Oct. 11		$\frac{2}{3}$
		Nov. 7		
Nov. 27 to Dec. 7	Dec. 2	Dec. 4		2
		31		
1892.				
Jan. 14 to Jan. 19	Jan. 16		Jan. 16	$2\frac{2}{3}$
			Feb. 12	
Feb. 26 to Mar. 10	Mar. 3		Mar. 10	2
Apr. 3 to Apr. 23	Apr. 13	Apr. 15	Apr. 6	$1\frac{1}{3}$
May 10 to May 18	May 14	May 12		1
		June 8		
June 29 to July 8	July 5	July 5		2
July 26 to Aug. 4	Aug. 1	Aug. 1		1
Aug. 25	Aug. 25	Aug. 28		1
Sept. 24	Sept. 24	Sept. 24		1
Oct. 30	Oct. 30		Oct. 30	$1\frac{1}{3}$

The frequent recurrence of an interval of about 27 days between the mean dates from April 23 to Sept. 24, 1892, suggested that there was a periodicity of this length running through the changes, and it was found that almost all the mean dates of change were separated by intervals of 27 days or some multiple of 27. It was found, furthermore, that all the mean dates of change could be arranged in two series of 27 day intervals, one series being separated from the other by about nine days, or one third of a period. If the dates of the period be taken as given in the third column of Table III., there are found 20 periods in the first series from April 8, 1891, to Sept. 24, 1892, with a

mean of 26.8 days, and eight periods in the second series from Aug. 30, 1891, to April 6, 1892, with a mean of 27.5 days. The mean of these two is 27.2 days which corresponds very closely with the time of a solar rotation determined from the best observations. There is a well-known period in the earth's magnetism corresponding with a solar rotation, and it appears probably from the above that there is also a meteorological period of the same length. It may be that there is a connection between magnetic and meteorological phenomena as claimed by Profs. Stewart and Bigelow.

In presenting radical interpretation of phenomena, however striking the evidence, one invariably encounters very strong scepticism as to its truth, and at times it seems to the investigator to arise merely from stubbornness about accepting new ideas; but on the other hand, it is very essential for the investigator to keep in view the possibility of deceiving himself, and mistaking ideas about phenomena for facts. For these reasons an effort was made to calculate the probability of the phenomena here presented being merely accidental. The calculation of probabilities is beset with difficulties, but there are a few conditions shown in this table which seem not to present great difficulties, and will be sufficient for the present purpose. If from Feb. 4, 7 A. M., to March 25, 1891, a perfectly regular period of 3 days and 2 hours be assumed, every observed maximum will fall within 16 hours of this period. Taking the entire 2 years, the frequency of intervals of 3 days and 2 hours ± 16 hours is found to be one fourth of all the intervals. Consequently, if there is no law governing their arrangement, the probability that one interval of this length will be immediately followed by another, is as 1 to 4; the probability that two will follow is as 1 to 16, etc., to the n — 1 power, taking n as the number of succeeding intervals. On this basis the probability that every one of 15 succeeding maxima should accidentally fall in a regular series of intervals, separated by 3 days 2 hours ± 16 hours is reckoned as 1 to 69,730,284. Again, from Oct. 15 to Nov. 23, 1891, there were 8 successive maxima, separated from each other by intervals varying in length between 5 days 4 hours, and 6 days 4 hours. The frequency of intervals between these lengths is to all the observed intervals as 1 to 8. Consequently, the probability that seven such intervals should accidentally follow each other is as 1 to 262,144.

In the same way the probability that the seven day period in May and June, and the six day periods in July, 1892, are accidental, are respectively as 1 to 81, 1 to 196, and 1 to 442. These figures, moreover, express only a fraction of the total probability that the coincidence shown in the tables were not due to chance. Besides all this, is the evidence of a seven day period presented in a previous article, where the regularity was so great for seven or eight intervals as almost entirely to preclude the theory of chance.

It seemed desirable to test what degree of success might be attained in predicting the temperature on the assumption of perfectly regular rhythmic oscillations and a knowledge of the time of their beginning and ending. To do this a double oscillation of six days four hours, or rather a single period of exactly three days two hours was assumed, beginning Feb. 4, at 7 A. M., 1891, and definite predictions were made for each day for the two months ending April 3. These predictions were worded like those made by the Weather Bureau, and were verified by the official rules of the Bureau, using for this purpose the 8 A. M. and 8 P. M. observations of the Blue Hill Observatory. The mean per cent of success was seventy-four, which is approximately that now obtained by the most skilled forecasters in predicting the temperature for thirty-six hours in advance.

Before this degree of success so long in advance can be attained, there are yet several questions to solve. First it must be known how many solar rotations any particular series will continue; second, what will be the length of the intervals, and third at what time the series will begin. The tables appear to indicate that the shorter the intervals the longer the series.

At present it is apparent that the dates of the series and the lengths of the intervals once being ascertained, the same period is likely to continue to the end of a solar rotation, so that for a large part of the year it is probable that forecasts can be made on this basis for a week or two in advance with nearly as much accuracy as they are now made for thirty-six hours.

Boston, April 6, 1893.

DISTRIBUTION OF PRECIPITATION IN TEXAS FOR THE YEAR 1892.

DR. I. M. CLINE, LOCAL FORECAST OFFICIAL, U. S. WEATHER BUREAU.

THE average precipitation in Texas, 29.28 inches during the year 1892, is only .17 of an inch below the normal. This conveys a general idea as to the rainfall in the State for the year when the general average is considered, but the normal for the State ranges from ten inches in the western portion of the State to about sixty inches in the eastern portion.

The rainfall for 1892 was not distributed in proportion to the normal rainfall for the different portions of the State. Over east Texas and the eastern portion of north Texas there was an excess ranging from twelve inches to twenty-five inches; over the central portion of north Texas there was an excess ranging from half an inch to three inches; and about the normal amount fell over the middle portion of central Texas, and the northern portion of the panhandle district. The rainfall was below the normal generally over other portions of the State. The deficiency over the coast district was greatest along the immediate coast, where it ranged from 16.99 inches at Corpus Christi to 27.55 inches at Galveston; away from the coast a little distance, the deficiency did not exceed eight or ten inches. Over the eastern portion of central Texas and southwest Texas the deficiency ranged from three to eight inches, and over the western portions of the State, and the southwestern portion of the panhandle district, the deficiency ranged from two to ten inches. The records of the separate months show nearly as unequal distribution over the different sections of the State as is shown by the records for the year.

Over east Texas the rainfall was near the average, or above, every month in the year except January, during which there was a deficiency ranging from one fourth of an inch to three inches. The greatest monthly excess occurred in June and December during which it ranged from three to seven inches, and in August and November, during which it ranged from two to five inches.

Over the coast district the rainfall was about normal in August and was deficient in other months except that it was about normal over the eastern portion in June and was three inches in excess over the west central portion in November. The greatest deficiency occurred in September, when it ranged from five to about seven inches. Over southwest Texas the rainfall was about normal, or above, in January, June, August, and October, and was generally one to two inches below in other months. The greatest excess occurred in August, when it ranged from two to nearly six inches. The greatest deficiency occurred in September when it ranged from two to nearly four inches.

Over central Texas the rainfall was about normal in November and December; was above normal in August and October, and was below normal in other months, except January it was below in north and above in south portion, and in March above in north, and below in south, and in June above in east, and below in west portion. The greatest excess occurred in October, when it ranged from two to three inches; and the greatest deficiency was three to four inches, in September.

Over north Texas the rainfall was above normal during March, May, October, and December and was below during other months, except in June and July it was above in east and below in west, and March and August below in central and above in east and west portions. The greatest excess was in October, when it ranged from three to nearly seven inches; and the greatest deficiency was in September, when it ranged from one to four inches.

August was the only month with rainfall about normal or above in all parts of the State. The departures from the normal for January and March were generally less than two inches, but in other months the precipitation was very unevenly distributed.

The following table shows the monthly rainfall for each district, and also the departure from the normal for the year 1892:—

PRECIPITATION DURING 1892.

	North Texas.	East Texas.	Central Texas.	S. W. Texas.	Coast District.
January	.98	2.09	1.20	1.69	1.74
February	.80	3.39	1.01	1.13	1.27
March	3.35	3.75	2.71	1.78	1.22
April	2.30	3.82	.91	.08	.60
May	5.64	3.78	3.98	1.95	1.05
June	3.91	9.15	2.92	3.22	2.53
July	2.22	2.21	1.60	.82	1.30
August	3.06	5.32	5.04	6.46	4.02
September	1.70	1.10	1.04	.73	1.22
October	6.33	3.96	4.51	2.97	2.74
November	1.25	6.60	1.70	1.06	4.18
December	3.21	8.50	2.88	4.40	1.20

DEPARTURES FROM NORMAL.

January	—1.00	—1.06	—1.35	+ .54	—2.02
February	—1.26	— .75	— .59	— .90	—1.98
March	+1.60	+ .12	+ .20	— .45	—2.06
April	—1.05	+ .01	—2.28	—3.38	—2.53
May	+1.86	— .97	—1.00	—1.51	—3.22
June	+ .20	+5.25	— .15	+1.19	—1.23
July	— .51	— .19	—1.22	—1.05	—1.53
August	— .30	+3.13	+2.07	+3.63	+ .14
September	—2.46	—2.19	—2.91	—3.33	—4.63
October	+3.98	+ .73	+2.11	+1.94	— .34
November	—1.32	+2.86	— .72	—1.15	— .81
December	+1.16	+4.86	+ .38	+3.25	—1.26

Minus (—) below normal; plus (+) above normal.

NOTE. — On account of the extensive area covered by the State, the great distances between its geographical limits, and its varied climate, that part of the State east of the 100th meridian has been divided into five sections. This has been done in order to enable more comprehensive discussions of the climatic conditions in their relation to agriculture and health. The coast district embraces that part of the State below the 100 feet contour line of elevation; East Texas, that part between the 100 feet contour line of elevation and latitude 32° 30′, east of longitude 96°; North Texas, that part north of latitude 32° 30′, east of the 100th meridian; Central Texas, that part between longitude 96° and 100° and latitude 30° and 32° 30′; Southwest Texas, that part between latitude 30° and the 100 feet contour line of elevation west of the 96th meridian. West of the 100th meridian that part north of latitude 34° is termed "The Panhandle," and that to the south is termed "West Texas."

CURRENT NOTES.

Royal Meteorological Society. — The monthly meeting of this Society was held on Wednesday evening, Feb. 15, at the Institution of Civil Engineers, 25 Great George Street, Westminster; Dr. C. Theodore Williams, President, in the chair.

Dr. J. H. Davies, Mr. G. F. Deacon, M. Inst. C. E., Mr. A. S. Helps and Mr. R. H. Jeffrey, B. A., were elected Fellows of the Society.

The following papers were read: —

1. "Report on the Phenological Observations for 1892," by Mr. E. Mawley, F. R. Met. Soc. The Royal Meteorological Society has for a number of years past collected observations on natural periodical phenomena, such as the date of the flowering of plants, the arrival, song and nesting of birds, the first appearance of insects, etc. These observations were supervised and discussed by the Rev. T. A. Preston until 1888, since which time they have been under the direction of Mr. E. Mawley. The year 1892 was on the whole very cold and backward. The frequent frosts and dry weather during the first five months greatly retarded vegetation, and consequently all the early wild flowers were very late in coming into blossom. Bush fruits and strawberries were, as a rule, good and fairly plentiful. Plums and pears were almost everywhere a failure, and apples were considerably under the average. The wheat crop was a very light one, owing in part to the attacks of blight brought on in many places by the frost in June. Oats, beans, and peas were much under the average, while barley was the chief crop of the year. Potatoes, turnips, and mangolds were above the average. During August butterflies were very numerous, the clouded yellow butterfly being exceptionally abundant.

2. "Relation between the Duration of Sunshine, the Amount of Cloud, and the Height of the Barometer," by Mr. W. Ellis, F. R. A. S. This is a discussion of the observations made at the Royal Observatory, Greenwich, during the fifteen years, 1877-91, from which it appears that in the months from February to October there is, on the whole, a distinct probability of increased sunshine and correspondingly less cloud with increase of barometer reading. The winter in all conditions of the barometer is uniformly dull. Mr. Ellis says that it is evident that high barometer in summer presages increased sunshine; that the effect is less pronounced in early spring and late autumn, and that it becomes slightly reversed in winter.

3. "Winter Temperatures on Mountain Summits," by Mr. W. Piffe Brown. In this paper the author gives the lowest winter temperature on the summit of Y Glyder fach, four miles E. N. E. from Snowdon, and 3,262 feet above sea level, as recorded by a minimum thermometer during

the last twenty-five years. The lowest temperature registered was 9° during the winter 1891-92.

At the monthly meeting of this Society held on Wednesday evening, March 15, at the Institution of Civil Engineers, Dr. C. Theodore Williams, President, in the chair, Mr. Shelford Bidwell, F. R. S., delivered a lecture on "Some Meteorological Problems," which was illustrated with numerous photographs and experiments. The lecturer said that one of the oldest and still unsolved problems of meteorology relates to the origin of atmospheric electricity. Many possible sources have been suggested, among them being the evaporation of water and the friction of dust-laden air against the earth's surface. Having granted some sufficient source of electrification, Mr. Bidwell said that it is not difficult to account for the ordinary phenomena of thunderstorms. Photography has shown that the lightning flash of the artists, formed of a number of perfectly straight lines arranged in a zig-zag, has no resemblance to anything in nature. The normal or typical flash is like the ordinary spark discharge of an electrical machine; it follows a sinuous course, strikingly similar to that of a river as shown upon a map. The several variations from the normal type all have their counterparts in the forms taken by the machine spark under different conditions, and the known properties of these artificial discharges may be assumed to afford some indication as to the nature of the corresponding natural flashes. Thus, for example, the ramified or branched flash, from which no doubt the dreaded "forked lightning" derives its name, is probably one of the most harmless forms of discharge. Ever since the time of Franklin, it has been customary to employ lightning rods for the protection of important buildings. According to Dr. Oliver Lodge these are of no use in the case of an "impulsive rush" discharge, which, however is of comparatively rare occurrence. Lightning conductors, however well constructed, cannot therefore be depended upon to afford perfect immunity from risk. Mr. Preece is of opinion that the "impulsive rush," though easily producible in the laboratory, never occurs in nature. Mr. Bidwell made some remarks as to the duration of a lightning flash and the causes of its proverbial quiver, and suggested an explanation of the characteristic darkness of thunder-clouds, and of the large rain drops which fall during a thundershower. The lecturer concluded with some observations concerning the probable cause of sunset colors, which he attributed to the presence of minute particles of dust in the air.

The Weather of India in June. — From the "Monthly Weather Review" of the Meteorological Department of the Government of India, for June, 1892, we take the following with reference to the weather of India in June:

"The most important feature of the meteorology of the month (and also of the year) is the advance of the southwest monsoon currents over the Arabian Sea and the Bay of Bengal into India and their establishment in the latter area. Brief and partial advances of these currents occur occasionally in the month of May, but it is usually not until the last week of May, or the first and second weeks of June, that the great advance occurs which culminates in the establishment of "the rainy season" in Central and Northern India.

"Judging solely from the land observations, there are very considerable differences from year to year in the character of the advance of the monsoon currents over the Indian seas towards Northern India. In one year (for example, 1889) the Bombay branch of monsoon current advances northwards along the west coast from Malabar to Bombay or Surat at a fairly uniform rate of progression, whilst in another year (for example, 1890) it appears to march westwards across the centre of the Arabian Sea and set in over the greater part of the west coast almost simultaneously. The manner of advance of the currents over India depends very largely upon the pressure and other weather conditions prevailing at the time in India, and hence differs largely from one year to another.

"Temperature is usually excessive in the whole of Upper and Central India at the commencement of the month. The advance of the monsoon currents over the interior increases humidity rapidly, and brings up much cloud and is followed by frequent rain-showers. Hence temperature falls rapidly with their advance, and the area of excessive temperature retreats northwestward to Sind, the West Punjab and Northwest Rajputana. The highest maximum temperatures of the year are hence occasionally recorded in that area in June or July.

"The change from great heat and dryness of the air to moderate heat, excessive humidity and frequent rain-showers is usually not completed over Northern India until the third or fourth week of June, by which time the monsoon currents usually penetrate into the East and North Punjab.

"There is always much disturbance and squally weather in front of the advancing monsoon. This squally weather, if conditions are favorable, may develop into a cyclonic storm. Hence cyclonic storms frequently accompany the great advance of the monsoon currents in the Arabian Sea and Bay of Bengal.

"After the southwest monsoon currents are fully established in Northern India small cyclonic storms form at short intervals in the Bay of Bengal or in Bengal. These storms form one of the more important and characteristic features of the rains. In June and July they usually march in a west or west-northwest direction along the trough of low pressure which generally stretches from Orissa to Sind or the Southwest Punjab, and which in its eastern half separates the area in which easterly winds from the Bay of Bengal prevail from the area in which westerly winds from the Bombay coast obtain. These storms not only give heavy rain to the areas they traverse, but draw rain away for the time being from other districts to concentrate it in the comparatively narrow belt over which they pass. They are hence one of the most important of the causes of the irregular distribution of the monsoon rainfall."

For further information as to the cyclonic storms of the Bay of Bengal, during June and later months, we refer our readers to the article by Mr. W. L. Dallas, on "The Appearance and Progressive Motion of Cyclones in the Indian Region," in the July number of this Journal, pages 99–112, and to that by Mr. S. M. Ballou, on "The Storms of India," in the November number, pages 300–307.

A Short Cycle in Weather. — In the March number of the *American Journal of Science*, Mr. James P. Hall has a paper entitled "A Short Cycle in Weather." From a study of the curves of the mean daily temperatures in New York City, it is seen that there are marked fluctuations every three or four days on the average, and that there is a tendency for the more prominent features of the curves to repeat themselves at intervals of about twenty-seven days. A comparison of the curves from New York, St. Louis, St. Paul, and Salt Lake City shows that these are closely parallel, but that the temperature changes in New York are a day or two behind those of St. Louis, two days behind those at St. Paul, and sometimes nearly a week behind those at Salt Lake City. This is, of course, due to the movement of cyclones and anticyclones in a general easterly direction across the United States, bringing with them changes of wind, temperature, and weather. The twenty-seven day period has been noted in connection with thunderstorms and other meteorological phenomena, and has been referred to the sun, whose period of rotation corresponds nearly with these cycles of weather. Investigations into this question of cycles are occupying the minds of many persons interested in meteorology in all parts of the world, and further contributions to the study of terrestrial magnetism, solar physics and kindred branches will undoubtedly throw much light on this at present rather obscure subject.

Jordan's Photographic Sunshine Recorder. — In this JOURNAL, on pages 345-349 of the present volume, Prof. C. F. Marvin gave an account of his new electrical sunshine recorder, and it may be interesting in this connection to describe briefly the photographic sunshine recorder invented by Mr. James B. Jordan, of London, and described in the Quarterly JOURNAL of the Royal Meteorological Society, Vol. XIV., pp. 212-215. This instrument is extensively used in England. It consists of two semi-cylindrical or D-shaped boxes, one containing the morning and the other the afternoon record. The beam of sunlight is admitted through an aperture in the centre of the rectangular side of each box. The semi-cylinders are placed with their faces at an angle of sixty degrees to each other; they are fixed on a triangular plate which is hinged to a suitable stand having levelling screws attached and fitted with a graduated arc, so that the cylinders may be readily adjusted to the proper vertical angle, agreeing with the latitude of the station where the instrument is used. The apertures for admitting the sunlight are so arranged that at the exact moment of noon the ray can enter both cylinders, but immediately after noon it can only enter the afternoon cylinder. Among the advantages which the inventor claims for his instrument are the tracing of the sunshine as a straight line at right angles to the hour lines on the chart, the ease of adjustment of the cylinders and the readiness with which the charts can be inserted and removed from the cylinders.

An Improved Soil Thermometer. — In the January number of *Agricultural Science*, Prof. C. F. Marvin gives a description of an improved soil thermometer, which he has developed conjointly with Prof. Milton Whitney. Soil temperatures determined by ordinary instruments are, as is well known,

rather inaccurate, and it is with a view of avoiding these errors as far as possible that this new style of thermometer has been invented. The bulb is almost wholly filled with alcohol, which acts as the principal thermometric fluid, and presents the advantages of a high co-efficient of expansion. The remainder of the bulb and the stem of the thermometer, up to a point convenient for graduation, is filled with mercury. In order to register the maximum and minimum temperatures, a short column of alcohol is placed in the upper portion of the stem, above the mercury, and within this are arranged two small indexes so constructed that they will not slide in the tube of their own weight, but are easily pushed upward by the mercury column or pulled downward by the top meniscus of the alcohol column. The instrument, when once set up, is very unlikely to become deranged.

Volcanoes as Weather-Vanes. — In the monthly summary of the observations at the stations of the Italian Meteorological Society notes are made of various volcanic phenomena observed during the preceding month at Stromboli, Vesuvius, and Etna, and in this connection the direction taken by the smoke from these volcanoes is tabulated. This is an interesting instance of one of the effects that physical features have on the meteorological data of any country.

CORRESPONDENCE.

THE DEFLECTIVE EFFECT OF THE EARTH'S ROTATION.

Editor of the American Meteorological Journal: —

For several years I have been securing by correspondence and otherwise as many estimates as possible of the extent of the deflections due to the effect of the earth's motion of rotation upon bodies free to change their location relative to its surface. Numerical values expressed in degrees of arc, or in units of linear measure or in any other form of precise quantitative statement have been sought. Of the answers thus far obtained, no two have agreed with each other, except where there has been direct quotation the one from the other, and not one has given a value that could by any possibility be construed in such a manner as to correspond with the angle which the wind arrows usually make with the isobars, as shown on the weather maps. With but one exception the answers obtained have been based upon the abstract discussion of trigonometrical functions, and do not appear to have been subjected to any comparison whatever with the wind directions actually recorded on the synoptic charts, or with any other facts of concrete experience, further than to state in a general way that deflection is toward the right or toward the left as the case may be. Thus the verifications generally have been qualitative rather than quantitative, and have failed to meet the requirements of the proposed research on the part of the writer. The single honorable exception is in the case of the value based upon actual experiments in regard to the deflections of the pendulum when free to swing in any direction under the conditions under which the experiment was first performed by Foucault. It is thus claimed to have been discovered that a pendulum swinging freely tends to remain in the same plane irrespective of the motion of the earth, and thus undergoes deflection relative to the latter. Thus at the pole a pendulum swinging in the same plane while the earth makes a complete revolution on its axis, will have changed the direction of its swing, apparently, through a complete circle or three hundred and sixty degrees in twenty-four hours. When thus suspended and swinging in lower latitudes, the time required to make such a complete circuit of changes of direction gradually increases until at the equator it becomes infinite, which signifies that there is no deflection whatever in that location. In other words, the deflection due to the earth's rotation is three hundred and sixty degrees in twenty-four hours at the poles, and a gradually decreasing number of degrees in the same limit of time in lower latitudes, reaching zero at the equator. This certainly affords a basis for comparisons in regard to the effects of the earth's motion of rotation on wind directions. As a matter of fact the sharpest and strongest

atmospheric whirls on a large scale, of which we have any knowledge, are tropical hurricanes, whose intensity and persistence is proportionate to the nearness to the equator of their point of origin. As such storms drift into higher latitudes their motion of rotation becomes decidedly less energetic as a rule. Thus if the pendulum experiments give a fair measure of the deflections due to the earth's rotation, the whirling of tropical cyclones must be due to some other cause, the strength and persistence of such whirls being altogether too great for the location in which they are found, and undergoing diminution instead of increase when they move into higher latitudes.

M. A. VEEDER.

LYONS, N. Y., Feb. 27, 1893.

ARE OUR WINTERS BECOMING MILDER?

Editor of the American Meteorological Journal.

The long continuance and severity of the winter just closing will certainly have a tendency to dispel the idea which has prevailed of late in the minds of some that our winters, at least in this section of the country, are not so cold as in former years. The record of the New Jersey weather service for the month of January last shows the lowest temperature so far known The chief minima were twenty-one degrees below zero at River Vale and Blairstown and fifteen below as far south as Woodbine, Cape May County. These are believed to be the lowest ever recorded.

In connection with this subject it may be of interest to mention some items gleaned from the final report of the New Jersey State geologist, published in 1888. Under the head of clinatology, he has compiled a series of notes on the weather affecting this section of the country, gathered from various sources, extending from 1607 to 1888. These are very brief, the character of the winter being shown largely by the condition of the Delaware and Hudson rivers, dates of closing and opening, whether navagible or full of ice. On selecting such winters as appeared to be sufficiently described to indicate their severity or mildness, I found one hundred and forty-eight which I placed in columns marked respectively cold and mild. On adding these up I was surprised to find the sum of each exactly alike, viz.: seven-four. This may, of course, have been partly accidental, as a slightly different arrangement might have been made; but it is safe to say that the results would not have differed greatly. There were frequently periods of four or five successive winters classed as mild. These would be invariably offset by several closely following winters classed as cold. The Hudson River would be frequently noted as open till very late for several seasons together, such notes as the following being made, "1754–5, winter unusually mild. Troops sailed from New York to Albany in January and February." During the three following winters the Delaware is also mentioned as being open most of the season. No doubt, then, as now, the idea would prevail, after such a period, that the winters were growing milder,

only to be dispelled by a succession of frigid seasons, of which the following is given as an instance. "1779-80. From November 25 to middle of March cold was intense and almost uninterrupted; snow nearly four feet deep for three months; the Sound was entirely covered with ice between Long Island and the main, and between New York and Staten Island. Troops crossed from New Jersey to Staten Island on the ice."

While the data at hand do not afford sufficient ground for saying that periodic changes occur in the severity of our winters, it is probably safe to predict that as the observations of our State weather services accumulate it will be found that the mean temperature of periods of say ten to twenty winters at a time will vary only slightly.

JOHN H. EADIE.

BAYONNE, N. J., March 11, 1893.

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MODERN METEOROLOGY.

FRANK WALDO, PH. D. *Modern Meteorology; an Outline of the Growth and present Condition of some of its Phases.* London, Walter Scott, 1893. 8vo. Pages xxiii., 460, illustrations 112.

Professor Waldo, who has for some years been physically unable to be present at his desk in the Weather Bureau at Washington, has improved the hours of his enforced retirement at Princeton, N. J., by the diligent prosecution of the study of meteorology. In addition to numerous special memoirs he has compiled the above-mentioned excellent work which is written in a style sufficiently popular to suit a large number of readers and at the same time sufficiently advanced to suit the desires of those who wish to get a glimpse of the condition and tendency of meteorology as it stood at the close of 1891, or at the time of the death of Prof. Wm. Ferrel. This volume is, therefore, an appropriate integral part of the Contemporary Science Series, and its moderate price, $1.25, puts it within the reach of any one who desires to acquaint himself with the current ideas as to instruments and theories in this rapidly advancing science. The general interests of meteorology have, we hope, been furthered by the appearance of this volume from an English press, which should insure it a wide circulation in British colonies as well as in America.

Prof. Waldo has divided his work into six chapters treating respectively of the history of recent progress; apparatus and methods; thermodynamics; general atmospheric circulation; special or secondary atmospheric circulations and, finally, climatology with its application to agriculture.

The second chapter on apparatus and methods embraces about one hundred and eighty pages, or more than one-third of the whole book, but, has perhaps not received any more prominence than this branch of the subject deserves, since Dr. Waldo has endeavored in all cases to emphasize recent improvements and the newest methods; he gives prominence to the important well-equipped meteorological observatories that are being established every where by private munificence.

The third chapter, on Thermodynamics, and the subsequent chapters on the General and the Secondary Atmospheric Circulation, occupy nearly one half of the volume. Of course these chapters can only give us a general exposition of the views of von Bezold, Ferrel, Hann, Hertz, Möller, Oberbeck, Sprung, and other leaders of modern thought on this subject. Fortunately those who wish to wrestle with the mathematical details into which these authors plunge their readers can do so by studying their collected

memoirs which have just been published in translation by the Smithsonian Institution under the title "Mechanics of the Atmosphere," a copy of which can be obtained by direct application to the secretary of that institution. But for those who wish to avoid mathematical symbols this present volume of Dr. Waldo's is undoubtedly the best available introduction to the study of the subject. It seems a singular coincidence that Waldo's "Modern Meteorology" and my own "Mechanics of the Atmosphere" should have been completed in manuscript during 1891 and published simultaneously in February, 1893, without either of us having any knowledge of the other's work; we cannot but be pleased to find that our works are mutually supplementary to each other. C. A.

THE WATERS OF THE ENGLISH CHANNEL.

H. N. DICKSON. *The Physical Conditions of the Waters of the English Channel.* Reprinted from the *Scottish Geographical Magazine* for January 1893. Pages 12, plates II.

Mr. Dickson, who was for some time a member of the Staff of the Marine Biological Association Laboratory at Plymouth, has recently made an investigation into the physical conditions of the waters of the English Channel. While the subject of his paper is not strictly meteorological, we consider that some brief mention of it should be made here. In plate I. we have the co-tidal lines for the channel, showing by numbers the interval of time in hours, between full and change of the moon and the first subsequent high water at the places through which the lines pass. The lines represent the progress up-channel of the great tidal wave that travels in a northeasterly direction from the South Atlantic, dividing at the southwestern extremity of England. The tides in the channel are considerably complicated by the configuration of the coast line, and also by the winds. When the latter are on-shore the tidal range is increased, and when they blow off-shore the range is decreased. With regard to the temperatures of the channel waters, Mr. Dickson finds that the temperature at any point remains sensibly constant at all depths more than six to eight fathoms below the surface. The upper layer of three to five fathoms is apparently subject to temporary local weather conditions. It appears further that there is an axis in the main body of the water along which the minima of temperature are found in summer and the maxima in winter. This is due to the fact that the temperature changes of the oceanic water of the Atlantic are propagated along the tidal stream of the channel. The motion of this water is sufficient to make its temperature uniform throughout, and there being but little motion of translation, the effect is to give the axis the characteristic of ocean water, viz., to make it a store house of warmth in winter and of cold in summer. The problems as to the effect of the winds on the tides, and of the temperatures of the water on the climates of the different parts of the coast, would be interesting subjects for further investigation.

THE RAINFALL OF AUSTRALIA IN 1891.

CHARLES TODD. *Rainfall in South Australia and the Northern Territory during* 1891 ; *with Weather Characteristics of each Month.* Adelaide, 1892. 4to, pages ix., 96 ; plates V.

The rainfall of Australia and of Tasmania presents a most interesting subject for investigation, and every new contribution to our knowledge in this connection is most welcome. A glance at a rainfall map of the world shows that the region of heavy rainfall in Australia is characteristically along the eastern coasts, while in Tasmania it is along the western coast. The reason for this difference is, chiefly, that Australia is in the region of the southeast trades, which, in their course towards the equator, impinge on the land mass of the Australian continent, and are forced to deposit much of their moisture there, continuing on their way across the western parts of that continent as drying winds, and thus causing the desert areas there found. In the case of Tasmania it is the prevailing westerlies which strike on the western edge of the land, and therefore that coast has the great rainfall.

The present report deals with the rainfall records of 1891, which are given in a series of monthly tables, with a review of the weather characteristics of each month at the end of the tables. The latter give the rainfall noted in 1891, and also the mean of previous years. A very complete set of tables of the observations at Adelaide gives records of the following: barometer, thermometer, temperature of evaporation, relative humidity, elastic force of vapor, solar radiation, terrestrial radiation, amount of cloud, sunshine, ozone, temperature of the soil, temperature of the sea, evaporation, wind, and other phenomena, such as thunder, lightning, frost, halos, etc. There are four maps besides the key map, showing the distribution of the rainfall in 1891.

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